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EXPERIMENTAL RECONSTRUCTION OF CARDIAC VALVES BY VENOUS AND PERICARDIAL GRAFTS*†

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RECENT DEVELOPMENTS in the surgical treatment of congenital cardiovascular disease^{6, 11, 20, 21, 29} and in improving the blood supply to the heart by operative means^{3, 18, 44} have stimulated interest in the surgical attack on other cardiac lesions. Despite the recent report of successful incision of a stenotic valve by Smithy,³⁸ and the method of closure of septal defects described by Murray,²⁶ it seems to us that effective surgical therapy of most intracardiac lesions will require operation under direct vision. This is not practical at present in man because of the lack of an adequate method for the extracorporeal maintenance of the circulation, with the blood stream excluded from the heart and lungs. In the experimental animal, however, intracardiac operations may be performed under direct vision during short periods in which both venae cavae are clamped. With the expectation that eventually a practical method of oxygenating large quantities of blood outside the body will permit operation in the open human heart, experiments were undertaken to determine whether grafted tissue could be used to replace a portion of a cardiac valve.

Intracardiac operations have been performed without interrupting the circulation. The procedures have been necessarily simple ones. Samways³⁴ in 1898 and later Brunton⁷ suggested surgical enlargement of the narrowed orifice in the treatment of mitral stenosis. Since that time many investigators, including Cushing and Branch,¹² Bernheim⁴ and Scheppelmann,³⁶ have experimentally divided valve leaflets using sharp knives thrust blindly into the heart. This method has been improved upon by Allen and Graham² who devised a cardioscope with an attached knife blade in order to see the structure being divided.

Cutler, Levine and Beck¹⁴ constructed a "cardiovalvulotome" and were the first to excise a portion of a stenotic mitral valve in human patients. Their first patient survived the operation and was apparently improved. However, in a review of all patients operated upon, Cutler and Beck¹³ in 1929 reported the deaths of their six later patients and of the single patients of Allen¹ and of Pribram.³³ Souttar's⁴⁰ patient, whose mitral valve was dilated digitally, sur-

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vived; as did the young man whose aortic valve was dilated by Tuffier.⁴² Prior to these operations Doyen¹⁶ attempted section of the pulmonary valve in a case of congenital pulmonary stenosis with a fatal result.

Early investigators in this field were handicapped by their inability to produce in experimental animals chronic valvular lesions similar to those seen in man. This difficulty was overcome by Powers and his associates^{30, 31, 32} who produced endocarditis by repeatedly damaging the valves of dogs with the electrocautery and injecting streptococci into the bloodstream. The surviving animals developed valve lesions closely resembling those seen in rheumatic human hearts. Five dogs, with mitral stenosis produced in this manner, were operated upon. A portion of the mitral valve was removed with the cardiovalvulotome of Cutler and Beck. All died of cardiac failure within nine days of operation.

Recently Harken^{23, 24} has been successful in establishing subacute bacterial endocarditis in dogs. He has also developed an improved cardioscope. Cohn¹⁰ produced interauricular septal defects in dogs and later succeeded in closing them. Smithy and Parker³⁹ incised aortic leaflets through the wall of the aorta. None of these operators interrupted the circulation.

Other investigators have interrupted the circulation and performed intracardiac operations under direct vision. Following Sauerbruch's³⁵ description of his method of compressing the base of the heart to control hemorrhage in the surgical treatment of cardiac wounds, Haecker²² in 1907, reported a series of operations within the hearts of dogs whose venae cavae were occluded. Carrel and Tuffier^{9, 42, 43} clamped the base of the heart in some of their fascinating experiments. O'Shaughnessy²⁸ attempted to prolong the period of circulatory arrest by perfusing the heads of his animals with a solution of hemoglobin. Björk⁵ working in Crafoord's laboratory has recently reported the successful perfusion of dogs' brains with oxygenated blood while both venae cavae were clamped. The experiments were performed under sterile conditions. Under these conditions the dogs survived, in good health, periods of occlusion as long as thirty-three minutes. Shaw and his associates³⁷ produced insufficiency and stenosis of valves on both sides of the heart in a large series of dogs whose cavae were temporarily occluded. In addition to operating with the venae cavae clamped, Fauteux¹⁷ performed some experiments in which the pulmonary artery was clamped and the left heart opened. Gibbon¹⁰ has perfused, under sterile conditions, the entire bodies of cats with oxygenated blood while the pulmonary artery was clamped. Prolonged survival in good health was reported following a period of occlusion of the pulmonary artery for 20 minutes.

Since we desired to operate within the open heart, under direct vision, preliminary experiments⁴¹ were performed to determine how long dogs could tolerate simultaneous clamping of both venae cavae. Clamping up to nine minutes produced no clinical evidence of permanent neurologic damage and the mortality rate was minimal.

The work of several earlier investigators was helpful in choosing tissue

EXPERIMENTAL RECONSTRUCTION CARDIAC VALVES

suitable for use as grafts. Jeger²⁵ formed valves in vein transplants in the dog by suturing the invaginated wall of the vein in such a way that two flaps were formed. One of these valves was patent and competent fourteen days after being placed in the carotid artery. In 1930, Wilson⁴⁵ reported placing strips of pericardium, tendon and fascia across the mitral orifice to produce stenosis. The pericardial strips remained viable and did not give rise to thrombus formation. Later Gordon Murray²⁷ threaded segments of vein which had been



FIG. 1.—*Above:* Resection of the valve cusp and papillary muscle.
Below: Temporary closure of the auricular incision.

turned inside out across the left ventricle to repair defects in the mitral valve made by the cardiovalvulotome. Two animals survived without evidence of cardiac decompensation. These reports suggested that either vein or pericardium might be suitable as a replacement for a cardiac valve. Grafts of potentially viable tissue were thought to be preferable to foreign material such as the ingenious methyl methacrylate valves placed in the aorta by Campbell.⁸ The following technic was therefore developed to allow resection of a portion of the tricuspid valve and its replacement with a graft of vein or pericardium.

TECHNIC

Dogs were anesthetized with nembutal, 25 mg. per Kg. body weight, intra-

venously. Air was administered endotracheally under intermittent positive pressure. The right pleural cavity was entered through the bed of the resected fourth rib. Both venae cavae were isolated and the azygos vein was ligated and divided or temporarily clamped. The pericardium was opened widely and two fine silk stay sutures placed in the wall of the right auricle.

Bulldog clamps were applied to both cavae completely occluding them. An incision about three centimeters long extending into the auricular process was made in the right auricle parallel to the annulus fibrosus. Very little bleeding occurred. Under direct vision the papillary muscle attached to the right cusp of the tricuspid valve was grasped and divided. With traction on the divided papillary muscle the right cusp was drawn into the auricle and divided along its base where it is attached to the wall of the heart (Fig. 1).

Saline solution was poured into the heart and the auricular incision quickly closed with a noncrushing Crafoord clamp. The bulldog clamps were removed from the cavae, re-establishing the circulation. The incision in the auricle was temporarily closed by a continuous suture and the Crafoord clamp removed (Fig. 1).

The graft was then prepared. If a vein was to be used, a generous segment of the azygos, with the supreme intercostal vein attached, was removed and pinned to a moistened cloth-covered board. The adventitia was stripped away and the vein turned inside out forming a T-shaped graft covered with vascular endothelium. The azygos vein formed the leaflet of the graft and the supreme intercostal vein the chorda tendinea. To prevent the graft from filling with blood, the open ends of the vein were closed with fine silk. Medium silk sutures were placed in the graft and tied after which they were again carried through the graft in order to approximate the graft directly to the endocardium. Usually three sutures were placed at the leaflet base and one at the apex of the chorda tendinea. To prevent rupture of the chorda the suture at its tip was continuous with the center suture at the base of the valve. The basal sutures were threaded through half circle round pointed needles and the apical suture through a long straight needle. The base of the graft was then transfixated with another long straight needle to permit it to be handled conveniently.

When pericardium was used, a portion, free from fat, was resected and trimmed to the desired size and shape on the board (Fig. 2, top). The suture and needle arrangement was the same as that described for the veins except that five sutures were placed at the base of the graft instead of three. Sometimes grafts of other shapes were prepared. Both venous and pericardial grafts with two chordae tendineae have been successfully implanted. The preparation of the graft required about 45 minutes. During this time the heart could recover from the effects of the first circulatory interruption.

The Crafoord clamp was then replaced on the auricle and the temporary suture in the auricular wound was removed. The cavae were re-clamped and the Crafoord clamp removed, again exposing the interior of the right side of the heart. The long straight needle attached to the suture in the chorda tendinea of the graft was passed into the base of the resected papillary muscle,

EXPERIMENTAL RECONSTRUCTION CARDIAC VALVES

through the interventricular septum and out near the apex of the heart. This suture was tightened and the graft moved down near the auricular incision and held there on its supporting needle by the assistant (Fig. 2A). The needles threaded through the sutures attached to the base of the graft were then

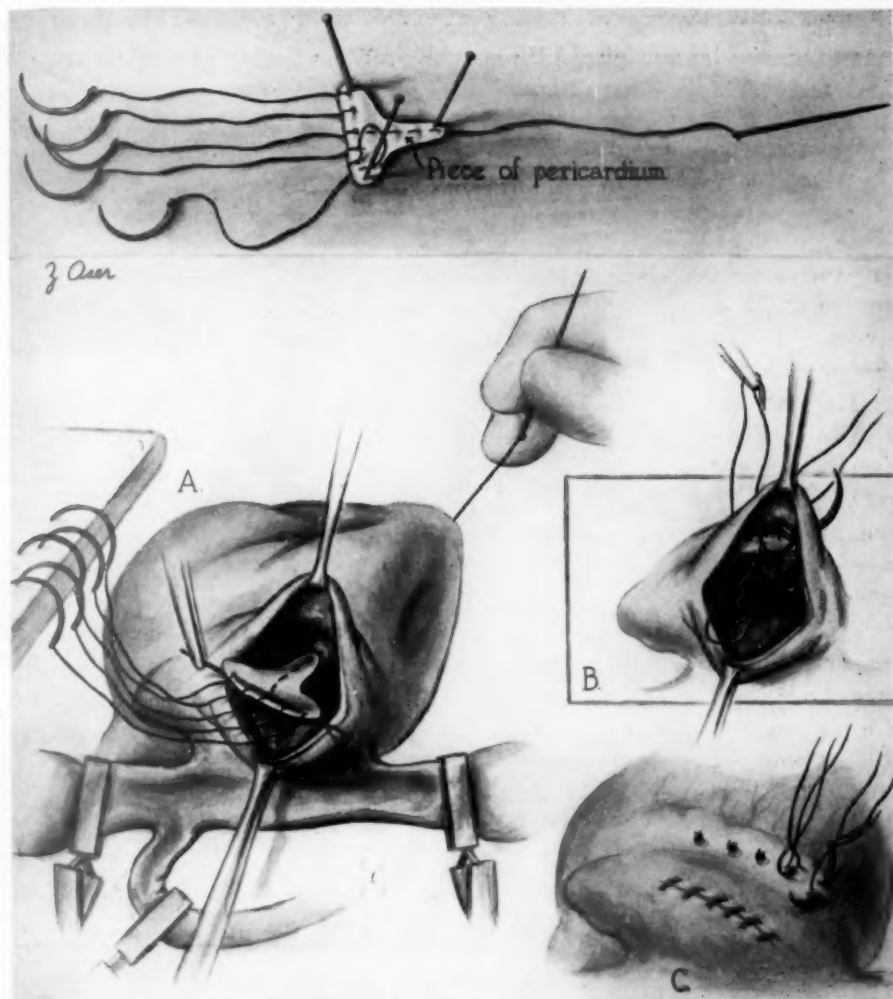


FIG. 2.—Above: Pericardial graft with attached sutures and needles.

Below: (A.) Apical suture placed through stump of papillary muscle, interventricular septum, and apex of heart.

(B.) Basal sutures placed through annulus fibrosus.

(C.) Auricular incision closed. Basal sutures tied.

passed through the annulus fibrosus from within outwards. While traction was made on all sutures the supporting needle was removed and the graft pulled into position (Fig. 2B). The right heart was filled with saline containing a few minims of a 1:1,000 solution of epinephrine hydrochloride. The

Crafoord clamp was replaced closing the auricular incision and the caval clamps removed. When necessary an additional intracardiac injection of 0.3 cc. of epinephrine solution was given and gentle cardiac massage instituted until strong contractions ensued. A continuous suture of fine silk was used to close the auricular incision.

The sutures holding the base of the graft were then secured by tying each one to another suture placed through the cardiac tissues at its point of exit from the wall of the heart (Fig. 2C). The apical suture was secured in similar

TABLE I

Experiment	Time of Death Days	Time of Sacrifice Days	Duration of Survival Months	Remarks
Venous Grafts				
1	0	..	..	Ventricular fibrillation
2	..	..	11	Living and well
3	9	..	..	Pericarditis
4	..	22	..	Living and well at time of sacrifice
5	0	..	..	Ventricular fibrillation
7	0	..	..	Ventricular fibrillation
8	..	4	..	Severe neurologic damage
9	0	..	..	Ventricular fibrillation
10	..	..	9	Living and well
Pericardial Grafts				
11	..	6	..	Severe neurologic damage
12	32	..	..	Infection about graft sutures
14	0	..	..	Ventricular fibrillation
16	1	..	..	Ventricular fibrillation
17	28	..	..	Distemper
23	0	..	..	Ventricular fibrillation
25	..	3	..	Severe neurologic damage
26	..	..	8	Living and well
29	..	..	8	Living and well
30	..	..	7	Living and well
Control				
19	..	36	..	Living and well at time of sacrifice
20	..	37	..	Living and well at time of sacrifice
21	..	40	..	Living and well at time of sacrifice
22	..	39	..	Living and well at time of sacrifice
24	..	..	8	Living, marked ascites

fashion. Care was taken to avoid injury to the coronary vessels. The pericardium was left partially open and the chest wall closed. One hundred thousand units of penicillin were placed in the pleural cavity and the same amount given intravenously. No anticoagulants were used.

The manipulations during the time the cavae were clamped were carried out as quickly as possible and every precaution was taken to avoid any technical error which might unduly prolong the time of circulatory interruption. In most of the operations adequate time was available to allow careful placing of sutures. Time required to resect a cusp of the valve averaged three minutes while suturing the graft in place took an average of six minutes.

In five control animals a leaflet of the tricuspid valve was resected as described above without replacement by a graft.

EXPERIMENTAL RECONSTRUCTION CARDIAC VALVES

RESULTS

The operation was performed on 19 dogs with the results shown in Table I. Six animals died at operation of ventricular fibrillation. One died the first postoperative day following successful defibrillation with electric current. Two animals died of infection on the ninth and 32d days respectively. Three animals, with evidence of severe damage to the central nervous system, were sacrificed during the first week.

Seven animals were living and well three weeks after the operation. One of these was sacrificed on the 22d day and one died of distemper on the 28th day. Five dogs survived from seven to eleven months after operation. They are apparently in good condition without evidence of circulatory impairment.

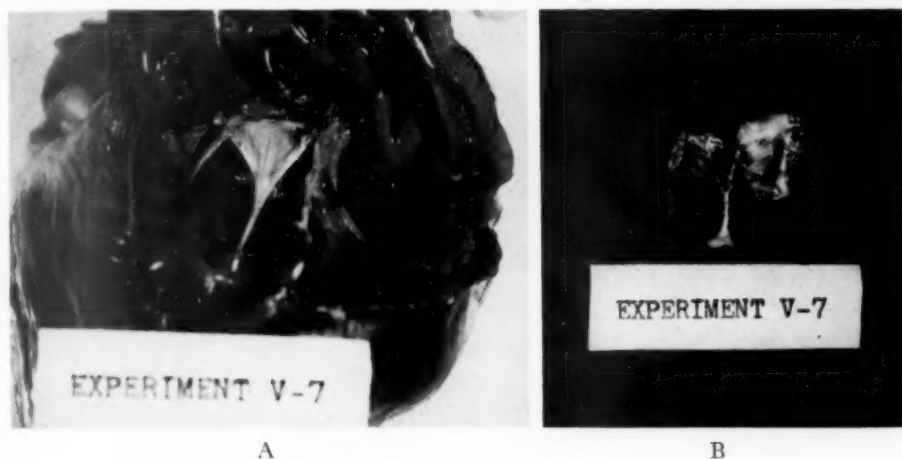


FIG. 3.—(A) Venous graft at completion of operation. (B) Resected portion of tricuspid valve.

The hearts of dogs that died at operation were examined to determine whether the grafts were properly placed. The other specimens, three venous and five pericardial grafts, were obtained at autopsy from one to 32 days after operation.

At autopsy none of the animals showed any gross evidence of circulatory failure. Intrapleural adhesions were present to a moderate degree. The pericardium was always adherent to the heart at the site of the auricular suture and there were usually a few adhesions to the surface of the heart elsewhere. The lung was frequently adherent to the heart where the pericardium had been removed. The auricular wounds and the sites of excision of the valve and papillary muscle were uniformly clean and free of thrombus formation except for one specimen in which a small, firm, densely adherent thrombus was present at one end of the auricular wound.

Specimens of grafted veins were obtained on the fourth, ninth, and 22d postoperative days. In every case the endothelial surface of the graft was smooth, shiny and free of clots. Two grafts were well placed and firmly adherent at all

points of suture. In the other specimen the sutures had not been pulled up snugly and the graft was suspended free in the ventricular cavity. When these grafts were placed in the heart they were flat and thin and resembled closely in appearance the normal valve cusp. At autopsy they were found to be swollen and thickened with resumption of their original rounded cross-section. Also no reinforcing suture had been placed through that part of the

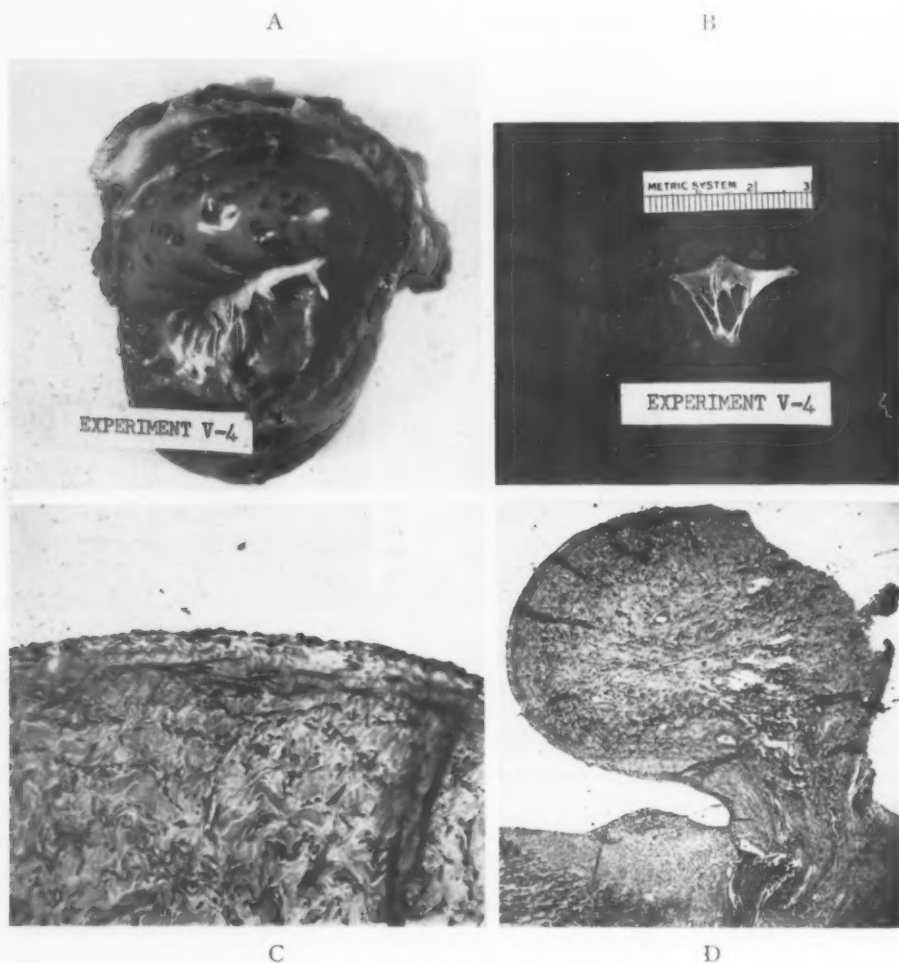


FIG. 4.—(A) Venous graft on twenty-second day. (B) Resected portion of tricuspid valve. (C) High power photomicrograph of surface of graft. (D) Low power photomicrograph, showing rounded cross-section of the graft with blood vessels in central portion.

graft forming the chorda tendinea in these three animals and rupture of the chorda had occurred in each case.

The microscopic sections confirmed the absence of thrombi in all three specimens. Union of the grafts to the heart wall was by firm fibrous tissue. The normal structures of the vein wall were seen in the four-day specimen.

EXPERIMENTAL RECONSTRUCTION CARDIAC VALVES

That obtained on the ninth day, showed evidence of an acute pancarditis with many bacteria and inflammatory cells present throughout the graft itself and all layers of the heart wall. There was no evidence of necrosis or inflammation in the 22-day specimen. Its rounded cross-section was filled with fibrous tissue containing many blood vessels. The appearance of these venous grafts at the end of the operation and after 22 days is illustrated in Figures 3 and 4.

Five specimens of pericardial grafts were obtained from the first to the 32d postoperative day. These grafts were all well placed and securely attached at all points of suture. The first and sixth day specimens were covered in part by a thin layer of thrombus more pronounced at the base, and the third day graft had a large white clot densely adherent to the ventricular surface.

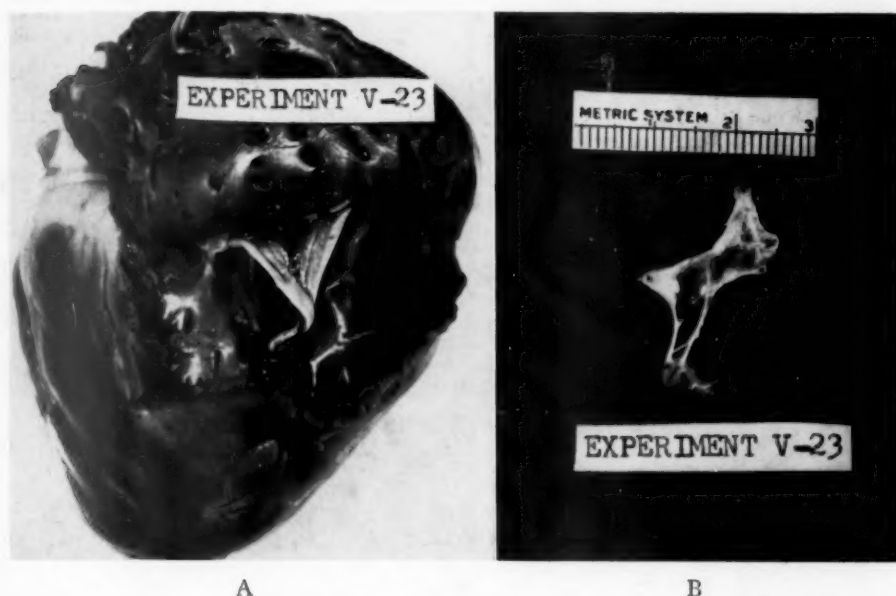


FIG. 5.—(A) Pericardial graft at completion of operation. (B) Resected portion of tricuspid valve.

Of particular interest was the appearance of the 28-day graft. Although several times thicker than at the time of implantation it was quite flexible and gave every indication of having been functional. Its covering blended imperceptibly with the endocardium at the points of attachment and the free edges were rounded and smooth. Microscopically there were no thrombi and the covering was similar to the adjacent endocardium. The body of the graft appeared to consist of fibrous tissue containing a few thin-walled blood vessels.

The heart of the animal that died on the 32d day showed evidence of severe localized infection with small abscess formation about each of the sutures in the graft. The graft itself was thick, nodular, and very firm and rigid. In the microscopic sections pericarditis and myocarditis were evident with areas of inflammation and necrosis surrounding the suture in the central portion of the

graft. Photographs of pericardial grafts, obtained at intervals after operation, appear in Figures 5, 6 and 7.

The five animals used as controls all survived the operation of tricuspid resection. Four of them were sacrificed during the seventh week, at which time

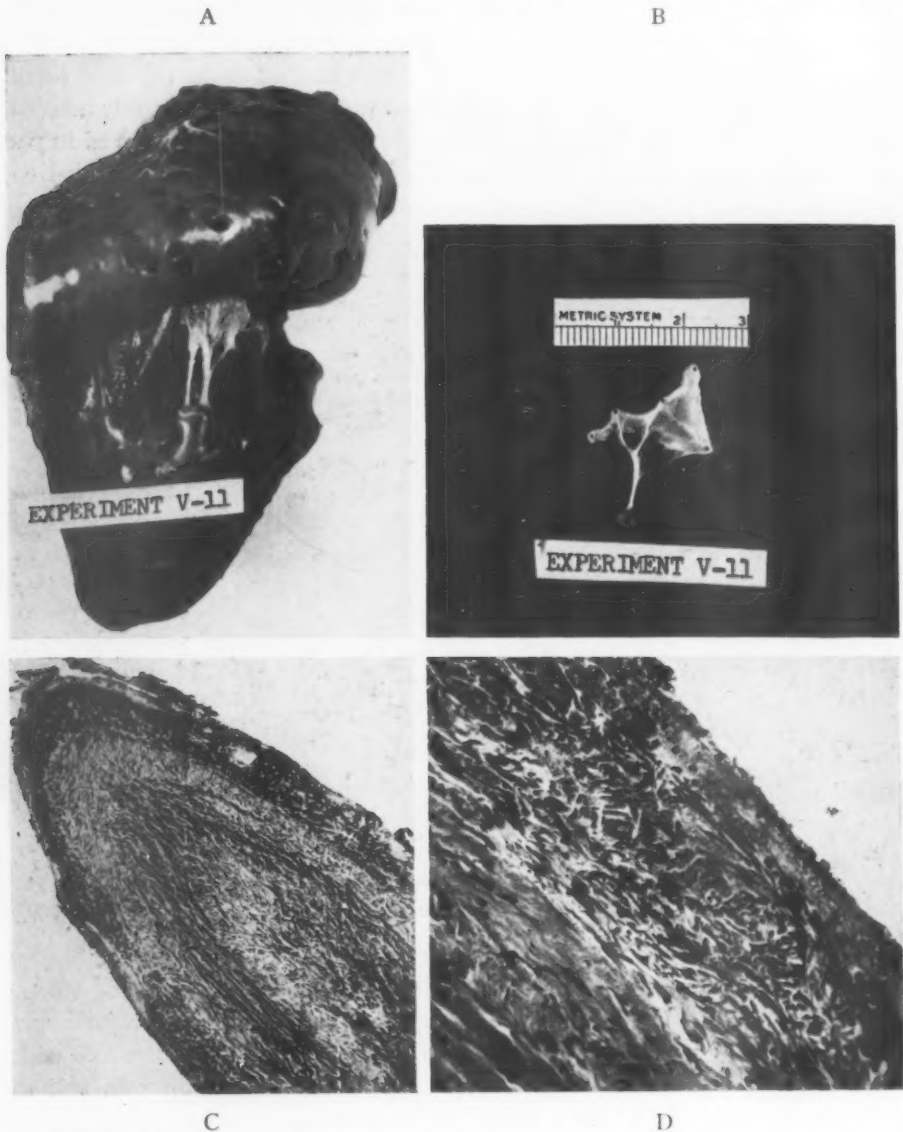


FIG. 6.—(A) Pericardial graft on sixth day. (B) Resected portion of tricuspid valve. (C) Low power photomicrograph at edge of graft. (D) High power photomicrograph showing thin layer of thrombus on surface of graft.

they were apparently well without evidence of cardiac decompensation. At autopsy it was found that from one-third to one-half of the tricuspid valve had been resected. The fifth animal is still living, but marked ascites developed

EXPERIMENTAL RECONSTRUCTION CARDIAC VALVES

approximately two months postoperatively, without other evidence of circulatory failure.

An attempt to evaluate the function of the grafts was made by contrasting the clinical findings in the seven grafted animals, who survived over three weeks without evidence of infection, with the findings in the controls. In

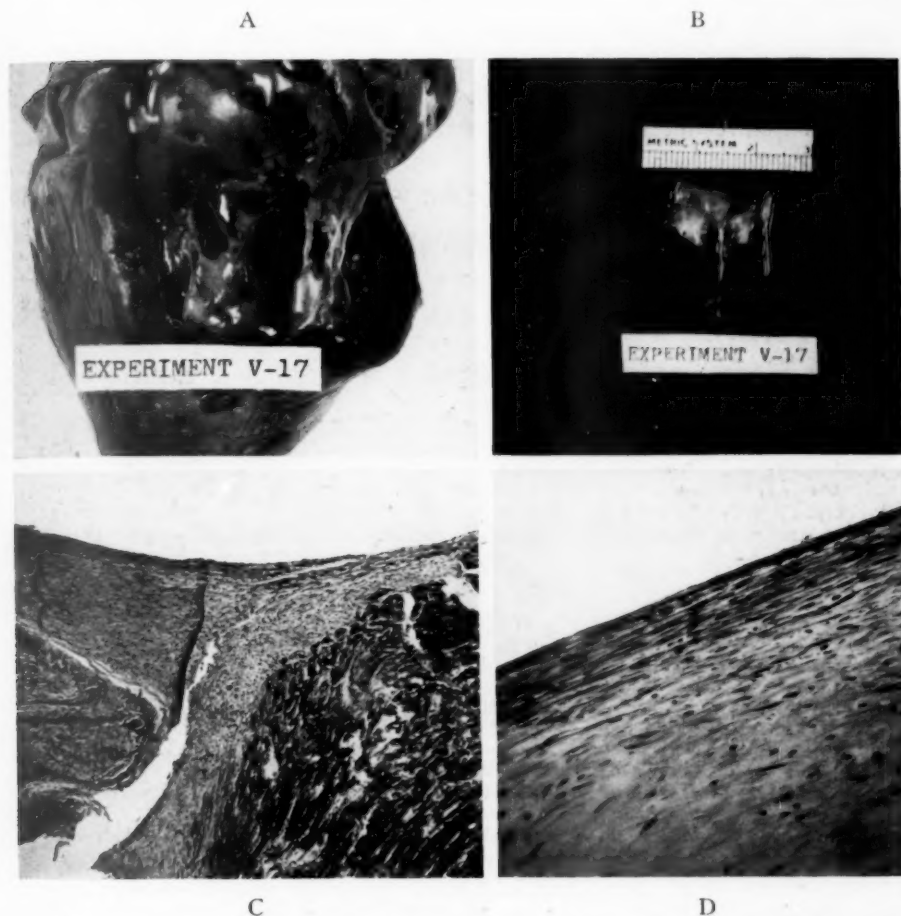


FIG. 7.—(A) Pericardial graft on twenty-eighth day. (B) Resected portion of tricuspid valve. (C) Low power photomicrograph at site of attachment to heart wall. (D) High power photomicrograph showing smooth surface free of thrombus.

keeping with previous reports of tricuspid lesions in dogs³⁷ only one animal, the control dog who developed ascites, showed evidence of circulatory failure. Venous pressures were not significantly elevated in either the grafted or control animals.

The results of electrocardiographic and phonocardiographic studies, together with notes on murmurs and thrills, are shown in Table II. All the control group had prominent systolic murmurs, confirmed by phonocardiogram, and marked systolic thrills. Electrocardiograms in the control group

were normal in two animals, revealed transient pericarditis in two, and early right ventricular strain in one.

All three animals with venous grafts had systolic murmurs of faint to moderate intensity but no systolic thrill. The murmurs were recorded by phonocardiograms in two of these animals. Electrocardiograms in the same two animals were normal. In the third animal (Fig. 4) separation of the chorda tendinea from the leaflet of the graft was found at autopsy. To prevent this occurrence the reinforcing suture was placed through the chordae of the later grafts including Experiment 10. No such suture was used in Experiment 2 whose chorda tendinea may also be torn.

Three of the four animals with pericardial grafts had no murmur at all and the fourth had a very soft systolic murmur. Phonocardiograms confirmed

TABLE II.—*Animals Surviving Over Three Weeks Without Infection.*

Experiment	Survival	Murmur	Thrill	Electrocardiogram	Phonocardiogram
Venous Grafts					
2	Living	Short systolic	None	Normal	Confirms murmur
4	Sacrifice 22 days	Faint systolic	None		
10	Living	Medium systolic	None	Normal	Confirms murmur
Pericardial Grafts					
17	Death 28 days Distemper	None	None		
26	Living	Soft systolic	None	Normal	Confirms murmur
29	Living	None	None	Transient pericarditis and right ventricular strain	Confirms absence of murmur
30	Living	None	None	Myocardial infarct	Confirms absence of murmur
Control					
19	Sacrifice 36 days	Loud systolic	Marked systolic	Right ventricular strain	Confirms murmur
20	Sacrifice 37 days	Moderate systolic	Marked systolic	Transient pericarditis	Confirms murmur
21	Sacrifice 40 days	Very loud systolic	Very marked systolic	Transient pericarditis	Confirms murmur
22	Sacrifice 39 days	Very loud systolic	Marked systolic	Normal	Confirms murmur
24	Living ascites	Moderate systolic	Marked systolic	Normal	Confirms murmur

these findings. In Figure 8 phonocardiograms are reproduced from a normal dog, from a typical control animal with tricuspid resection alone, and from two dogs with pericardial grafts but without murmurs or thrills. There were no palpable thrills in any of the four animals. Electrocardiograms were normal in one dog, showed transient right ventricular strain and pericarditis in another, and myocardial infarction in a third. This infarct could have resulted from damage to the right coronary artery by a suture, or by the electric shocks used to treat ventricular fibrillation at operation since one of the electrodes was found to be improperly padded.

DISCUSSION

The disadvantages inherent in any technic in which complete interruption of the circulation is necessary have been emphasized by other authors.^{2, 16, 17, 32}

EXPERIMENTAL RECONSTRUCTION CARDIAC VALVES

The large number of deaths from ventricular fibrillation in our series and the occurrence of severe neurologic damage in three animals indicate that these disadvantages have not been overcome. In spite of this it has been possible to replace the resected portion of a cardiac valve with a graft sutured under direct vision.

Morphologically the pericardial grafts appear to be better than the venous grafts. Although covered with vascular endothelium and free of thrombi the veins tended to become swollen and revert to their original round cross-section losing the valve-like shape which they had at the time of operation. The pericardial grafts, on the other hand, remained thin and flexible and appeared to

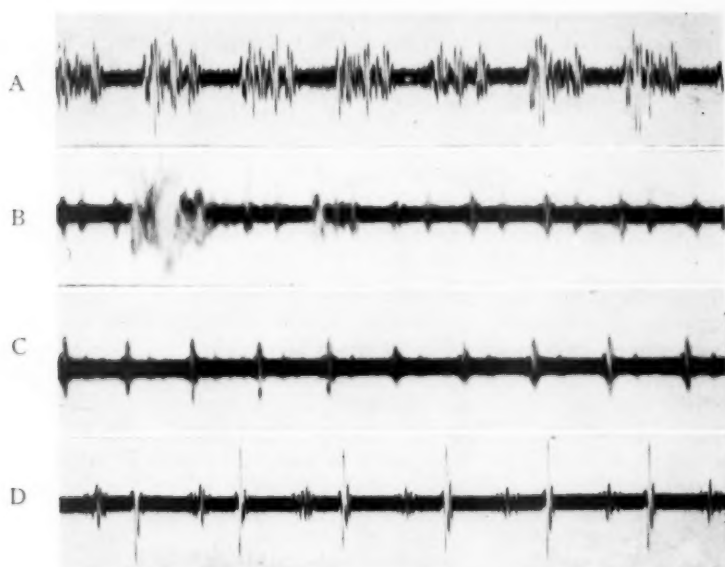


FIG. 8.—Phonocardiograms:

- A. Control dog with resection alone. (Experiment 19)
- B. Pericardial graft (Experiment 30). (The blurring of the graphic record in two places is due to respiratory movements.)
- C. Pericardial graft. (Experiment 29)
- D. Normal dog.

meet the morphologic requirements for functional valves. The early specimens had a thin layer of thrombus formation and in one specimen a large clot was present. The late specimens were only slightly thickened and had a smooth shiny surface.

Clinically the pericardial grafts also gave better results. Three of four dogs had no murmur and thrill, one to eight months after operation. In contrast the dogs with venous grafts all had systolic murmurs and the control dogs without grafts had marked murmurs and thrill and one developed ascites.

A temporary extracorporeal circulation should greatly reduce the mortality of intracardiac operations under direct vision. Deaths from damage to the central nervous system and from ventricular fibrillation should be eliminated,

because of the adequate supply of oxygenated blood to the cerebral and coronary arteries. In addition the surgeon should be able to perform more meticulous and extensive operations, because he will not be limited to the few minutes of circulatory interruption that the brain will tolerate.

SUMMARY

1. In 19 dogs, a cusp of the tricuspid valve was replaced by a graft of vein or pericardium sutured in position under direct vision.
2. Seven of these dogs survived in apparent good health from three weeks to seven months after operation.
3. Specimens of the grafts obtained at autopsy after three weeks were viable and firmly united to the wall of the heart.
4. In five control animals a portion of the tricuspid valve was resected and no graft was used. Postoperatively these animals had loud murmurs and marked precordial thrills, in contrast to the grafted animals in which there were no thrills and faint, or no, murmurs.
5. Anatomically and functionally the pericardium appeared to be more suitable than a vein as a source for the graft.

SUPPLEMENTARY NOTE

Since submission of this article for publication, changes have occurred in the state of the surviving animals. Animals 2 and 10 (vein grafts) have developed palpable thrills, and the murmurs previously heard have increased in intensity. Dog 10 was sacrificed. The right heart was enlarged and the graft was cord-like and useless. It was attached only at one end of the base and at the apex. Animals 26, 29 and 30 (pericardial grafts) have systolic murmurs of moderate intensity, and a systolic thrill can be felt in dogs 26 and 30. Dog 26 was sacrificed. The heart was normal in size with a well-placed, intact, firmly attached graft. The surface was shiny and blended smoothly with the endocardium. The leaflet, however, was somewhat contracted upwards toward the base.

ACKNOWLEDGMENTS

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THE METABOLISM OF CALCIUM IN PATIENTS WITH SPINAL CORD INJURIES*

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RECUMBENCY HAS BEEN RECOGNIZED as an important factor in the genesis of urinary tract calculi.^{5, 11, 21} The literature concerning the factors involved in calculus formation is very extensive.^{3, 17, 20, 22, 23} Considering that the major factors include recumbency, stasis, infection, and dietary dyscrasias, it is not at all surprising that patients suffering from injury to the spinal cord should have a high incidence of calculi in the urinary tract. The following report is based on observations made on over 700 young male adults (ages 18-50) who had suffered injury to the spinal cord during and shortly after World War II.

In the first world-wide conflict, concentration of patients with spinal cord injury at special hospitals led Head and Riddoch¹⁵ to list the course of paraplegia in four stages. These were: (1) The stage of flaccidity which began with the onset of the injury and continued for about six weeks; (2) The stage of spasticity when reflex activity developed and gradually increased in severity; (3) The stage of paraplegia in flexion when the spastic contractions had continued to the point where contractures had developed; and (4) The stage of loss of reflex activity which developed as debility and sepsis advanced, with death as the final culmination. Undoubtedly, the history of the patients from the recent war would have been the same were it not for the advent of anti-bacterial agents and the recognition of the need for highly supervised bladder care such as that described by Munro.²⁶ As a consequence of these advances, the outlook for the patient with spinal cord injury was improved. Despite this, two grave problems remained—the high incidence of urinary tract calculi with the concomitant presence of severe urinary tract infection, and the debilitating effect of huge decubitus ulcers. The latter problem was solved by the development of surgical technics such as those of Gibbon & Freeman¹⁴ and others.^{2, 7, 32} The former was more difficult to solve, for the treatment of the injury was recumbency, and mobilization could not be accomplished since the lower limbs (and in quadriplegias, all four limbs) were paralyzed. To attempt an answer, certain data appeared to be necessary.

INCIDENCE OF URINARY TRACT CALCULI

Survey of the initial group of 90 patients demonstrated that renal stones were present in 15 and bladder stones in 12, or an overall incidence

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of 30 per cent. Subsequent analyses of other groups of patients showed that 38.4 per cent of 164, and 27 per cent of 280 had urinary tract calculi in the first months of injury. These figures were in accord with those observed at other centers for the care of paraplegic patients.¹⁸

a. *Relationship to age.* The age range of these patients was from 18 to 50 years with the average age being approximately 25 years. No correlation could be observed between age and incidence of calculus formation.

b. *Relationship to level of lesion.* With lesions ranging from the fourth cervical dermatome down, no correlation between the level of the lesion and the incidence of stone formation could be observed.

c. *Relation to dietary intake of calcium.* Most of the patients were severely restricted in the amount of calcium in their diet during the early part of our experience. A few, however, insisted on liberal allotments of milk, cheese, and ice cream without any noticeable difference in the incidence of calculi.

d. *Relation to urinary calcium excretion.* With limited laboratory facilities available, a rough quantitation of the amount of calcium excreted in the urine by the "quantitative" Sulkowitch test⁴ was undertaken. To test the accuracy of the method, samples of urine from normal ambulant males were submitted at intervals along with the test samples, all as unknowns. Normals were found to excrete approximately 150 milligrams of calcium daily in 1500 cubic centimeters of urine by the method used. Despite the relative inaccuracies of the method, there was little question about the fact that the patients with extremely high daily excretions of calcium were "stone formers." Conversely, those with low daily outputs of calcium did not form stones. Because of this finding, a study of the factors entering into the increased excretion of calcium (and the formation of stones) was undertaken.

RECUMBENCY

Recumbency was the most obvious feature to examine first. Patients showed daily excretions of calcium in excess of 500 mg. as early as the first week after injury. Since careful fluid intake and output records were kept on most of the patients, various other correlations were found. Among these were the fact that despite extremely high daily outputs of calcium (over 500 mg.), provided the concentration were kept below 15 mg. per cent, stones rarely formed. The concentration was directly related to the fluid intake and with the advent of strict adherence to a schedule of more than 4,000 cc. of fluid intake daily, the incidence of calculus formation was noted to fall. Even with this precaution, the per cent of "stone formers" remained at about 20 per cent. Consequently, to test concomitantly the factor of fractures of major bones *per se* and the factor of recumbency, 93 cases of arm fracture and 87 cases of leg fracture were surveyed.²³ The cases with fracture of the arm were all ambulant, only the injured extremity being immobilized. No stones were found in these cases and the average urinary calcium excretions were within normal limits. In the leg fracture cases, 19 per cent showed the presence of urinary tract calculi, principally in the bladder. In these cases, the level of calcium

CALCIUM METABOLISM WITH SPINAL INJURIES

excretion was uniformly higher than normal, ranging from 125-350 mg. daily, and stones were found in those with the greatest calcium excretions. This observation is in agreement with the studies of Flocks.¹¹ There appeared to be no difference between femoral fractures treated with suspended traction and those treated with casts. This point is also borne out by the observation that paraplegic patients with almost continuous reflex spastic activity of the legs were as vulnerable to the formation of stones as were those with complete flaccidity. As such, it appeared likely that the principal factor involved was not recumbency alone, nor the presence of a fracture of a major bone, but the absence of weight-bearing on the long bones of the legs. To test this hypothesis,

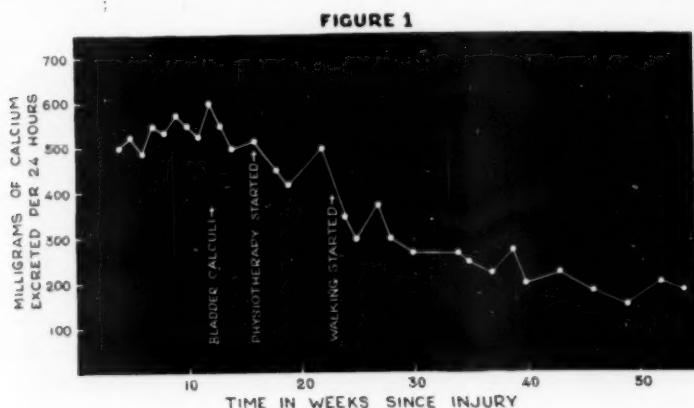


FIG. 1.—Patient with injury to spinal cord at D₁₂ dermatome. This patient was one of the first to ambulate and demonstrates the sharp drop in urinary calcium excretion coincident with this procedure. Later, when his right hip dislocated and ambulation had to be discontinued, stones reformed in the bladder.

paraplegic patients were first mobilized in wheel chairs, but high urinary calcium excretions were maintained despite this change. Then, they were equipped with crude metal straps as long leg braces. Following even feeble attempts at ambulation in a walker, calcium excretion fell markedly in all patients studied. The events from the time of initial observation to the conclusion of the period are represented graphically for two patients in Figures 1 and 2. These cases show the major features very strikingly, and the resultant lessons learned gave impetus to the development of technics which would allow for early and vigorous ambulation.¹³

Blood studies failed to reveal a single instance of significant elevation of total blood calcium. No change in blood phosphorous or phosphatase was noted in a group of 12 cases. Further study is definitely needed in this sphere, for complete and well regulated studies were not carried out, due to exigencies beyond control.

The role of *Vitamin D* was investigated, but in more than 25 patients, liberal doses failed to alter the excretion of calcium, and no change was noted on its withdrawal.

Vitamin A was also administered, but in these patients, the presence or absence of supplemental dosages failed to alter the course of excretion to any significant degree.

Time seemed, at first, to be a major factor, for on cursory analysis of the figures, the rate of stone formation and the level of calcium excretion usually fell sharply at about the eighth month. However, subsequent analysis demonstrated that these phenomena occurred coincidentally with the institution of ambulation.

Vicarious deposition of calcium salts. Certain patients showed peculiar depositions of roentgen ray opaque material in the soft tissues about the hip joints. Some of these depositions showed bone lines. It was tentatively decided

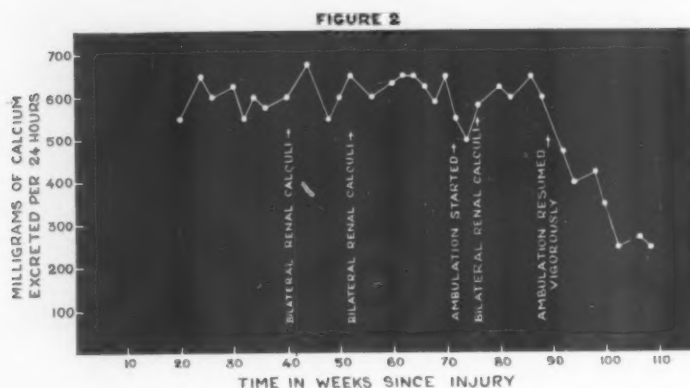


FIG. 2.—A patient with a spinal cord transection at D₄ dermatome. Despite the numerous examples of the benefits derived from ambulation, this patient refused to consider the difficult task of ambulation until his life was jeopardized. The resulting drop in calcium excretion is dramatically illustrated.

to label these cases as "neurogenic ossifying fibromyositis," not because it was felt that nervous influences were important, but because the condition seemed to be peculiar to patients with paraplegia. The appearance of a report by Soule,³¹ in which it was stated that the condition appeared to be peculiar to paraplegia but was not associated with other factors, prompted a resurvey of the problem. No cases had been seen in which there was not or had not been an overlying, infected, pocketed, decubitus ulcer. We had originally postulated that the presence of bacteria had instituted changes in the relations of the calcium-phosphorus balance through the local production of enzymes (phosphatase) or local changes in acid-base balance. Several patients were found with similar changes about the knees where no ulcers had ever been. It was felt, however, that these cases merely represented the spread of infectious processes along fascial planes with concomitant local changes. Apparently, this condition is similar to that described by Dejerine *et al.*¹⁰ These authors found calcification in 48.7 per cent of paraplegic patients and believed that the process was one of metaplasia.

In reference to Soule's report,³¹ it must be borne in mind that the external appearance of a decubitus ulcer is always deceiving. On superficial inspection, it will not be found that the ulcers usually penetrate the subcutaneous tissues and reach wide dimensions in the deep tissues. Thus, our concern largely rested on a means of separating cases of neurogenic ossifying fibromyositis from those of frank osteomyelitis with calcific depositions. Since a number of cases were seen in which neither violent trauma nor trauma incident to physical therapy could be implicated, it was felt that other factors were responsible. Biopsy specimens from two cases grew *Staphylococcus albus* in one and *Staphylococcus aureus* in the other. From this observation, it can not be argued that infection is invariably present, but it still is remarkable that in the only two cases examined (both with healed decubiti) organisms should be cultured from the heart of the calcifications.

In many roentgenograms, calcification of the rib cartilages was seen to have progressed to an advanced degree. A review of some 30 cases from the standpoint of possible gallbladder stones failed to reveal a single instance.

DISCUSSION

The factor of recumbency has been emphasized in the discussion of important features in the formation of urinary tract calculi,^{5, 11, 21} but insufficient stress has been given to actual weight-bearing. The phases of calcium metabolism that occur during childhood with the rapid formation of new bone apparently are no longer present in the adult. As such, the counterpart must lie in the stages of recanalization of the Haversian canals that occur after weight-bearing begins; biopsy or autopsy material was insufficient to permit definite conclusions. It would appear from available data that changes coincident with weight-bearing reflect an alteration in the utilization of calcium. The analysis of Albright *et al*¹ would indicate that in the absence of usual stresses and strains of activity and weight bearing, osteoblastic activity is decreased. The decreased formation of organic matrix in the face of normal rates of resorption would produce a demineralization of the immobilized bones and a hypercalcinuria. Roentgenograms invariably show the decalcified state of the bones of the pelvic girdle and legs during recumbency with marked increase in density after the assumption of the erect, weight-bearing position. It would appear that careful studies carried out during these stages would reveal many of the important factors in bone formation. Analysis of the calculi removed from these patients at operation almost uniformly showed calcium and phosphorus as the principal constituents, with carbon occurring frequently. Crystallographic examinations reveal the similarity of urinary calculi to the inorganic fraction of bone.^{12, 16} It has been demonstrated that the diffusible fraction of blood calcium, *i.e.*, the ionized calcium, increases with recumbency.⁶ Excitement, likewise, increases the excretion of calcium, as do the sympathomimetic drugs.²⁷ Few are the paraplegic patients who do not show a reduced total protein with a reversal of the albumin-globulin ratio. When coupled with normal blood calcium levels, this would imply an increase in the ionized calcium²⁵ and thus an increase in the

calcium available for participation in bone, or stone, formation. Shorr *et al.*^{9, 28, 29, 30} have conducted studies on the relationship between calcium excretion and the excretion of citric acid. They point out that citrate tends to keep calcium in solution, enhanced by an alkaline medium, but diminished by the presence of bacteria which reduce the citrate content. Estrogenic hormones uniformly augment the excretion of citric acid and androgens reduce it. They also studied normal males confined in casts and showed an excretion of calcium double that of normal but considerably less than that shown by Howard¹⁹ in fracture patients. Since gynecomastia and testicular atrophy and destruction have been observed in paraplegic patients, one can imply that, in some, there are hormonal factors which might help prevent the formation of calculi.

The role of infection and of the hydrogen ion concentration of the urine were of great importance in calculus formation, for most cases studied had infection of the urinary tract, almost always with urea-splitting organisms, and thus were unfit candidates for acidification of the urine for prolonged periods of time.^{8, 28} Despite clinical control of these infections, bacteriuria was still present. While granting that the roles of stasis and infection in the formation of urinary tract calculi may be great, the major disorder in the paraplegic patient probably lies ahead of excretion, and the presence of calculi merely reflects the abnormally high withdrawal of calcium from the bones and its excretion in the urine.

As has been pointed out by Howard,^{19, 21} once a high level of calcium excretion in the urine is obtained, not much can be done to alter the rate of excretion if the mechanisms for homeostasis remain within normal limits. This would explain the failure to find abnormal blood levels of calcium and phosphorous in paraplegic patients. This is emphasized by the discussion of Albright *et al.*¹ These authors point out that osteoporosis is primarily a disorder of tissue metabolism and only secondarily of calcium metabolism. As such, blood calcium, phosphorous, and phosphatase levels can be expected to be within normal limits. The resultant hypercalcinuria could be predicted from this analysis.

Much study is needed before conclusive answers are obtained. In a few autopsy specimens, it was felt by one pathologist that the parathyroid glands exhibited evidences of hyperplasia. Granted that this be true, whether it exists as a primary or as a compensatory phenomenon is not apparent. It can only be hoped that answers to these problems will be sought and found in the vast number of paraplegic patients still in hospitals.

SUMMARY

1. A review of clinical experiences with over 700 paraplegic patients with special reference to calcium metabolism is presented.
2. The incidence of urinary tract calculi approximates 23-35 per cent during prolonged recumbency.
3. Ambulation reduces the incidence of calculi to such a degree that the

presence of a calculus can be taken as an indication of the failure to ambulate sufficiently.

4. Neurogenic ossifying fibromyositis is discussed as a reflection of the aberrant state of calcium metabolism in the presence of infectious and inflammatory processes.

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DISPLACEMENT OF THE ESOPHAGUS INTO A NEW DIAPHRAGMATIC ORIFICE IN THE REPAIR OF PARA-ESOPHAGEAL AND ESOPHAGEAL HIATUS HERNIA*†

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TYPES

THE PHRASE, HIATUS HERNIA, unqualified, refers only to the herniation which occurs at the esophageal hiatus.

There are three main types of esophageal hiatus hernia:

1. Short esophagus with "thoracic" stomach (rare)
2. Normal esophagus; the stomach herniates about the esophagus into the hernial sac. However, the esophagus remains in its normal situation and does not occupy a position in the sac (para-esophageal). (Approximately 33 per cent of instances)
3. Normal esophagus; the stomach herniates through the esophageal hiatus pushing the esophagus ahead of it into the sac. (Approximately 66 per cent of instances)

The first type probably is not a true hernia of the stomach into the hiatus, as the stomach never occupied a position in the abdomen. It represents a true congenital anomaly. The other two types are also congenital, however, only in the sense that an inguinal hernia is congenital. Even though these defects are present from birth, no symptoms are usually present until the patient is 40 years or older. Apparently, it is usually necessary to have other concomitant abnormalities present before symptoms are produced. These abnormalities are in a sense accompaniments of the aging process viz., the stretching of tissue, the loss of elastic fibers, a decrease of fat in the esophageal ring, and an increase in the intra-abdominal pressure, secondary to obesity, cough, constipation, pregnancy, and ascites.¹

FREQUENCY

By no means a rare defect, it has been estimated that under the conditions of general medical practice, symptoms sufficient to bring the patient to the roentgenologist for a gastro-intestinal study will result in the discovery of an esophageal hiatus hernia in two out of every 100 patients examined.⁹

Harrington⁵ operating upon 500 patients for other reasons, found that in 65 per cent, the diaphragmatic relations were normal; in the remaining 35 per cent, one or more fingers could be inserted between the esophagus and the diaphragm. This peculiarity exists more often after the fourth decade and

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occurs more frequently in females. Ude and Rigler¹¹ noted that females outnumbered males 15:4. The majority of patients were advanced in age, revealing histories of multiple pregnancies, some with intra-abdominal tumors and ascites. Rigler and Eneboe⁸ attempted to evaluate the effect of increased intra-abdominal pressure in the development of hiatus hernia. They subjected women in the third trimester of pregnancy to roentgen-ray examination of the stomach. They concluded that small hernias through the esophageal hiatus were found in 18.1 per cent of multiparas and in 12.8 per cent of all cases. In seven positive cases, the hernia was not demonstrable after parturition.

RECOGNITION

In general, the symptomatology depends upon the mechanical interference to the function of the herniated organs *per se* or by the pressure on those organs encroached upon within the thoracic cage. Obviously a wide range of variables are present from patient to patient and within the same patient at different times. Therefore, it is possible to have symptoms referable to the gastro-intestinal tract, the cardiovascular system, the respiratory tract, or any combination of these systems.¹³

Physical examination contributes little to the diagnosis. Most patients are past 40 years of age and obese. "Inspiratory borborygmi"⁷ are unusual except in very large hiatus hernias.

Roentgen-ray examination is the most important single diagnostic aid available. The patient must be examined in many different positions and particularly in the recumbent and prone positions. In the upright position many hiatus hernias will reduce themselves spontaneously. If one suspects an esophageal hiatus hernia, this suspicion should be conveyed to the roentgenologist. Otherwise a routine upper gastro-intestinal series will be done and the diagnosis may be missed. Once the diagnosis of hiatus hernia is established, it is difficult at times to determine the presence or absence of additional pathology at the lower end of the esophagus.

There are two important occurrences one must bear in mind in this condition:

1. There is often no correlation between the size of the hernia and the severity of the symptoms, although as a general rule small hernias do not produce symptoms.
2. The hiatus hernia may be an incidental finding. Therefore, one should rule out, by all means available, the presence of any other lesion which may be responsible for the patient's symptoms.

TREATMENT

Once the diagnosis of esophageal hiatus hernia is established, and other causes for the patient's symptoms have been excluded, two modes of therapy are available, viz., conservative or operative.

Medical conservative management should be attempted in practically all cases. The most important single item with regard to good medical management consists of reducing the patient's weight. Many patients without fixation

DISPLACEMENT OF ESOPHAGUS

of the stomach to the hernial ring (as evidenced by the reduction of the herniated viscus under fluoroscopy when the upright position is assumed) will be helped materially by the reduction of weight alone. Adjuvant measures include a bland diet taken as frequent small feedings, antacids, antispasmodics, sedatives, and the correction of constipation and flatulence. These patients should be advised to maintain an upright or semi-upright position after eating and also to avoid exercise after meals. Most patients will be benefited by sleeping with the thorax higher than the abdomen. For acute symptoms, nitroglycerin taken before meals and on retiring is of value. Surgical repair is justified after medical measures fail to give relief. Certain cases, because of the presence of adhesions or associated abnormalities, e.g., volvulus of the stomach, or the possibility of a more serious lesion of the distal end of the esophagus, are surgical problems at the outset and should be explored without any unusual delay.

In the past, the reconstruction of the esophageal hiatus has consisted of the displacement of the esophagus posteriorly against the vertebral column with application of the tissue about the diaphragmatic defect anteriorly and laterally utilizing various types of suture material. The scarcity of tissue of sufficiently good quality posteriorly to close the defect satisfactorily constitutes the disadvantage of this type of repair. Consequently, a space posteriorly results, which remains open to receive once again a subsequent herniation of the stomach into the thorax. In addition, the replacement of the esophagus into the same site it previously occupied, obliges one to attempt the repair with tissue, which previously was unable to withstand the existing stresses and strains arising in the relationship of the diaphragm and the adjacent abdominal viscera. The possibility of a recurrence in this area following the conventional type of repair appears to be a real one and might well explain many of the failures and recurrences reported in the literature.

The following material concerns itself with the presentation of 13 cases of esophageal hiatus hernia (exclusive of those cases associated with a congenitally short esophagus) treated surgically. A variation of the conventional repair was suggested by one of us, (O. H. W.)¹² and such a closure was first performed on October 25, 1944; since that time it has been employed in all cases. This repair entails essentially the displacement of the esophagus anteriorly and to the left, the closure of the diaphragm posteriorly, and the suturing of the stomach immediately distal to the esophago-gastric junction to the edge of the diaphragm with fine silk sutures. This method of repair fulfills all the requisites for a satisfactory hernioplasty, viz., displacement of the conduit (in this instance the esophagus) away from the weakened structures, utilization of healthy tissue in an anatomic reconstruction of the area, and the use of a non-absorbable suture.

Singleton (1942),¹⁰ in discussing a paper by Harrington, stated that he had repaired two esophageal hiatus hernias by anterior displacement of the esophagus. It may well be that others have done the same. Since that time no formal presentation has appeared in the literature to our knowledge.

PREOPERATIVE CARE

The conventional standard preoperative care is carried out, including the passing of a duodenal tube into the stomach prior to surgery. Continuous suction is applied to the inlying duodenal tube before any attempt is made to induce the anesthesia. Suction is employed during the operative procedure and is continued throughout this period. Anesthesia has consisted of either cycloprane and curare or a pentothal and curare mixture.² An intratracheal tube with an inflatable cuff has been used in all cases regardless of whether the operative approach has been thoracic or abdominal.

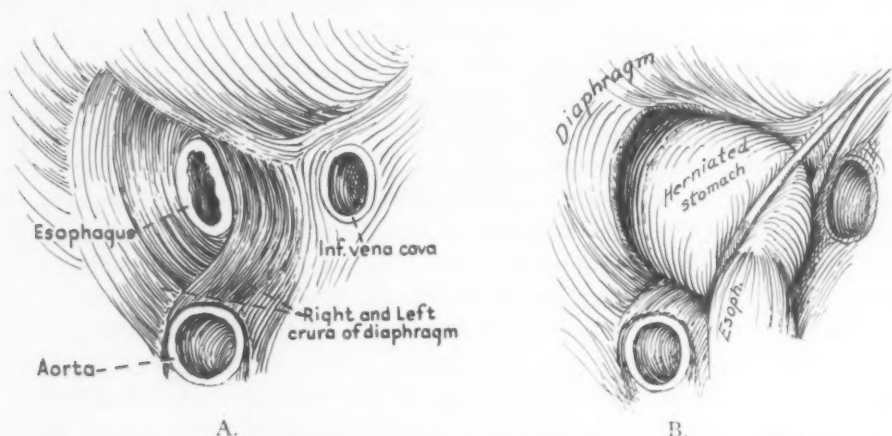


FIG. 1.—(A) This sketch represents the normal anatomy of the esophageal hiatus as it appears looking down upon the diaphragm from above.
(B)—The usual picture of an esophageal hiatus hernia after mobilization.

TECHNIC OF REPAIR

Transthoracic Approach. The position of the patient is a semi-lateral one with the left side elevated, the patient's back making approximately a 45 degree angle with the table. An oblique incision is made over the 9th intercostal space. In the initial operations, a segment of the 9th rib was resected. This procedure has been found to be unnecessary and has been abandoned in subsequent cases. The 9th intercostal space is incised and the pleural cavity is entered. The phrenic nerve then is crushed at its entrance into the diaphragm. The hernia is readily discernible in the triangle formed by the left ventricle, the aorta, and the diaphragm. The sac is incised and partially excised, and the edge of the hernial ring is freshened. The stomach and the esophagus are mobilized and displaced antero-laterally into the most anterior portion of the hernial defect. The right and left crura of the diaphragm then are sutured together behind the esophagus with 000 silk sutures. If the consistency and the quality of the tissue posteriorly are unsatisfactory for suture or a satisfactory approximation of the diaphragmatic crura behind the esophagus is not made readily, extending the incision into the anterior portion of the left leaf of the diaphragm facilitates this part of the procedure. Moreover, this maneuver is in accord with the best principles of hernioplasty, viz., moving the esophagus to an area where a snug anatomic closure of strong tissues can be made

DISPLACEMENT OF ESOPHAGUS

about it. Additional sutures of 0000 silk are taken from the free edge of the diaphragm to the esophago-gastric junction, preferably on the stomach side (See Fig. 1 & 2 & 3). The chest closure is effected by three pericostal sutures of double strands of 0 chromic catgut, care being observed that the elements of the intercostal bundle are not caught in the suture. The remainder of the chest wall closure is accomplished by interrupted fine silk sutures in multiple layers.

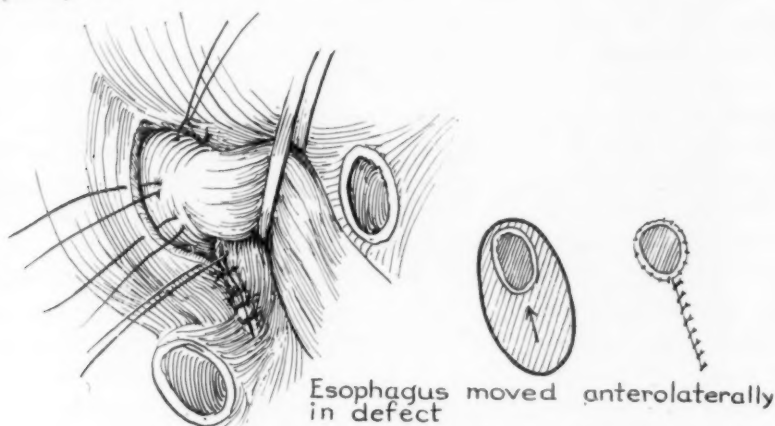


FIG. 2.—The herniated portion of the stomach has been replaced into the abdomen. The esophagus has been displaced anteriorly and laterally into the original defect and a closure has been effected posteriorly by suture of the right and left crura of the diaphragm. Additional sutures have been taken from the upper portion of the stomach immediately distal to the esophago-gastric junction to the edges of the diaphragm.

The inset drawings illustrate the repair diagrammatically.

This type of repair is indicated when the tissues posteriorly are of sufficiently good quality for satisfactory suture.

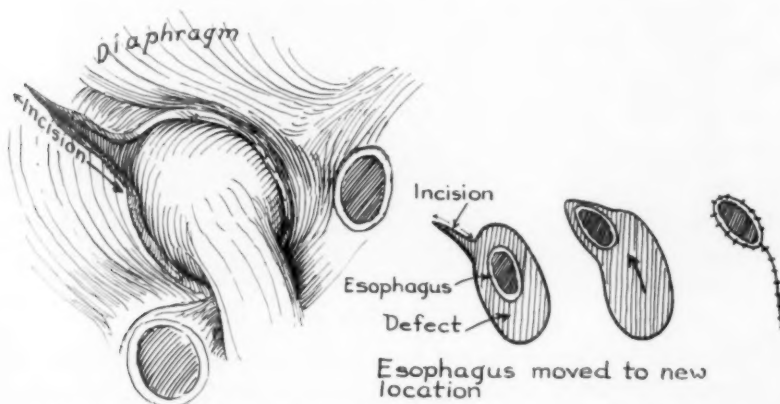


FIG. 3.—When the tissues of the right and left crura are not satisfactory for suture, a new esophageal hiatus is created.

The principles of repair are identical in all respects to those indicated under Figure 2.

In both drawings, the closure of the diaphragm posterior has been shown to be complete. This is not always possible from the thoracic approach. However, two or three well-placed sutures posteriorly approximating the diaphragm suffices to insure a good result.

Abdominal Approach. The patient is operated upon in the supine position. A subcostal incision is employed. All bleeding is controlled with fine catgut and silk. The gastro-colic ligament is identified, and an appropriate sized opening is made into the lesser omental sac. With traction upon the stomach downward and medially combined with manipulation about the hernial site, reduction can usually be accomplished. At times the severance of adhesions will be necessary. The hernial ring is freshened; the sac is not excised. The stomach and esophagus are displaced anteriorly and the right and left crura of the diaphragm are sutured together with 000 silk. Usually it is possible to close the posterior defect completely from the abdominal approach. Additional sutures are taken about the periphery of the hernial ring to the uppermost portion of the stomach, with attention to the avoidance of inclusion of the vagus nerves in the suture. The abdominal closure is completed by multiple layers of 000 and 0000 silk.

Combined Abdomino-thoracic or Thoraco-abdominal Approach. The patient is placed supine on the table with the left side moderately elevated. The left arm is elevated and/or placed across the chest. The incision begins at the right lateral border of the right rectus abdominus muscle, and is continued obliquely upward crossing the mid-line half-way between the xiphoid process and the umbilicus. Abdominal exploration then may be done. If abdominal pathology is present, the incision can be extended towards either side of the abdomen. In the absence of abdominal pathology or if there is need for a combined abdomino-thoracic exposure, the incision may be continued into the 9th intercostal space on the left side. This necessitates the section of a single cartilage.

The repair of the esophageal hiatus or para-esophageal hernia is effected in the same manner as previously described for the transthoracic approach by anterior displacement of the esophagus and closure behind of the right and left crura of the diaphragm.

Others^{3, 4, 6} have advocated this combined approach for lesions of the lower end of esophagus, the upper end of the stomach, and for diseases of the spleen.

Obviously, if the original incision is transthoracic, if necessary the incision may be converted into a combined thoraco-abdominal approach in the presence of a lesion in the lower esophagus or upper stomach.

POSTOPERATIVE CARE

Postoperative suction is applied to the inlying duodenal tube for 24 to 48 hours. During this period appropriate amounts of sodium chloride and glucose solution are administered intravenously. When the patient tolerates well the clamping of the nasal tube, it is removed. A gradual increase in the diet is allowed. All patients have been ambulatory within the first few postoperative days. If an undue amount of fluid accumulates in the pleural cavity, aspirations occasionally may be necessary.

A



B

FIG. 4.—Case No. 2 U. H. No. 749179. These x-rays represent two independent upper gastro-intestinal series taken postoperatively. The phenomena present may represent vagus nerve injury. (A.)—(11/22/44) The stomach is filled with food and fluid although the patient had not had either for at least 15 hours. Peristalsis appears to be very slow but moderately active. Emptying takes place very slowly. Amyl nitrite was inhaled and the patient obtained a marked physiologic response but with little effect on the emptying of the stomach. (B.)—(5/21/45) After an interval of six months, another gastro-intestinal series revealed a markedly dilated proximal end of the stomach with a considerable accumulation of food and fluid. An extraordinary type of hour-glass constriction was shown in the middle third of the stomach, but the remaining portion of the stomach from that point on was rather sinuous and narrow. About seven and one-half hours after the barium was given, a small amount passed through the pylorus into the first portion of the duodenum. Emptying time was extremely slow. Larocaine instilled through a stomach tube had no effect upon the configuration of the stomach.

RESULTS AND DISCUSSION

Thirteen cases of hiatus and para-esophageal hernias of the diaphragm have been repaired by the technic described herein. Nine cases were approached through the thorax; three through the abdomen, and one by the trans-abdomino-thoracic route. (See Table I). No recurrences have been observed in this small group of cases in followup periods varying from five to 36 months. The two methods of repair used have proven to be simple and efficacious, the avoidance of the vagus nerve being the only consideration necessary other than the actual repair itself. This danger is inherent in any repair of an esophageal hiatus hernia. (Case 2, Table I) probably represents an example of injury to the vagus nerves (See Figure 4).

The repair may be accomplished with facility through the chest or abdomen. Because of the ease of access to and exposure of the hiatus area, and the simplicity of obtaining a secure anatomic repair the transthoracic approach is to be preferred. In those cases in which the crura of the diaphragm posteriorly are not satisfactory for closure behind the displaced esophagus, we have found it advantageous to make an incision into the normal anterior margin of the left leaf of the diaphragm in order to have available healthy normal tissue for a solid closure posteriorly. This maneuver can only be accomplished safely through the thorax. In this fashion an entirely new site is created for the esophageal bed. One must be careful to avoid the possibility of too snug a closure about the esophagus itself. The presence of the inlying duodenal tube helps the surgeon decide this matter.

Certain disadvantages of this approach have become apparent as experience has accumulated. In one instance (Case 2, Table I) a carcinoma of the transverse colon was overlooked. Undoubtedly this lesion was present at the time of the initial operation for the diaphragmatic repair. Although one is able to do a moderately satisfactory abdominal exploration transdiaphragmatically through a thoracic incision, in the event of the presence of intra-abdominal pathology the efforts of the surgeon will be gravely hampered by this approach. The disadvantages to the operator may be modified somewhat by the conversion of the thoracic incision into a combined thoraco-abdominal one by the section of the costal cartilage and the anterior abdominal wall.

After any intrathoracic operation, a serous effusion follows. This transudate represents a normal protective response of the pleura to trauma. The effusion is usually small and of no consequence. However, when hemostasis has been incomplete, a bloody effusion results. The dangers of a chronic hemothorax have been well documented. (Case 6, Table I) is an example of such a complication. A multiloculated empyema cavity resulted, which necessitated surgical drainage and a rather prolonged convalescence. Although the empyema healed completely on drainage alone, it might have been wiser to have performed a decortication of the lung early in the convalescent period. As has been related earlier, however, most effusions are of a minor nature. Although the potential danger of secondary infection is ever present, the use of antibiotics has in a large measure obviated this danger. In view of the fact

DISPLACEMENT OF ESOPHAGUS

TABLE I.—*Transthoracic Approach*

Symptoms	Preop. Diagnosis	Operation	Complications	Result
Severe. 1. F. S. UH No. 749117. 46 year old white male. Date of operation 10/25/44. Discharge 11/3/44.	Para-esophageal hernia.	Esophagus displaced anterolaterally with suture of the right and left crura behind.	None.	Norecurrence of hernia. Symptom free.
Mild, of short duration. Some vomiting. 2. A. L. UH No. 749174. 39 year old white female. Date of operation 11/1/44. Discharge 11/8/44.	Massive hiatus hernia, partial volvulus of the stomach.	Incision into the diaphragm with suture behind.	Massive atelectasis right with effusion and gastric retention. Readmitted 5/3/45 with carcinoma of transverse colon with radical resection. Expired 6/7/45. Gastric retention still present.	No recurrence of hernia at autopsy.
Mild to moderate nausea and vomiting periodically since childhood. 3. F. M. UH No. 750827. 18 year old white male. Date of operation 1/31/45. Discharge 2/7/45.	Massive diaphragmatic hernia with a portion of the stomach in the right chest.	Esophagus displaced anteriorly with suture of right and left crura behind.	None.	Norecurrence of hernia. Symptom free.
Dysphagia with severe symptoms. 4. L. O. UH No. 755718. 64 year old white female. Date of operation 7/17/45. Discharge 7/28/45.	Large hiatus hernia; ? carcinoma of lower esophagus.	Esophagus displaced anterolaterally with suture of crura behind.	None.	Norecurrence of hernia. Symptom free.
Moderately severe. 5. E. W. UH No. 710007. 55 year old colored female. Date of operation 7/19/45. Discharge 7/28/45.	Recurrent hiatus hernia; previous abdominal repair of the conventional type.	Esophagus displaced anterolaterally with suture of crura behind.	None.	Norecurrence of hernia. Symptom free.
Severe. 6. N. O. UH No. 757889. 37 year old white male. Date of operation 9/21/45. Discharge 9/26/45.	Hiatus hernia.	Esophagus displaced anterolaterally with suture of crura behind.	Readmitted 10/1/45 with multiloculated empyema, left; drained in multiple sites.	Norecurrence of hernia. Symptom free. Patient has residual symptoms related to his obliterated pleural cavity.
Severe dysphagia. 7. E. E. UH No. 764597. 64 year old white female. Date of operation 4/12/46. Discharge 4/20/46.	Hiatus hernia.	Esophagus displaced anterolaterally with suture of crura behind.	Some dysphagia to solid foods for a temporary period.	Norecurrence of hernia. Symptom free.

TABLE I (Cont'd)—*Transthoracic Approach*

Symptoms	Preop. Diagnosis	Operation	Complications	Result
8. I. P. UH No. 764516. 64 year old white female. Date of operation 5/10/46. Discharge 5/14/46.	Dysphagia; severe. Para-esophageal hernia. ? Esophageal stricture; ? car- cinoma.	Esophagus displaced antero- laterally with suture of crura behind.	None.	Norecurrence of hernia. Symptom free.
9. F. M. UH No. 766153. 69 year old white male. Date of operation 7/16/46. Discharge 7/27/46.	Severe; vomiting. Hema- tenesis. Massive hiatus hernia. Vo- lulus of the stomach.	Incision into diaphragm with suture behind.	Some gastric retention with pyloric obstruction. Re- explored transabdominally 7/28/46. The adhesions creating torsion were severed.	No recurrence of hiatus hernia. Periodic dis- comfort. Weight gain Markedly improved.
10. E. W. UH No. 616650. 60 year old white female. Date of operation 3/26/46. Discharge 4/1/46.	Moderately severe; refer- able to para-esophageal her- nia and/or gall bladder. Para-esophageal hernia. ? cholecystitis.	Esophagus displaced antero- laterally with suture of right and left crura behind; chole- cystectomy.	None.	Norecurrence of hernia. Symptom free.
11. T. K. UH No. 766421. 59 year old white female. Date of operation 8/1/46. Discharge 8/7/46.	Weakness, weight loss; se- vere anemia secondary to GI bleeding. ? of ulcer in stomach at constricted area of esophagus. Arthritis.	Esophagus displaced antero- laterally with suture of right and left crura behind. Sub- total gastrectomy. Appen- dectomy.	None.	Norecurrence of hernia. Gain in weight, etc.
12. F. M. UH No. 773601. 59 year old white female. Date of operation 1/14/47. Discharge 1/19/47.	Moderately severe. Three previous bouts of hema- temesis and melena.	Esophagus displaced antero- laterally with suture of right and left crura behind. Splen- ectomy. Appendectomy.	None, except for slight wound infection.	Norecurrence of hernia. Symptom free.
13. W. T. UH No. 777834. 61 year old white male. Date of operation 5/12/47. Discharge 5/23/47.	Moderate with slight acid eructations. Frequent small feedings with sensation of fullness.	<i>Abdomino-Thoracic Approach</i> Displacement of esophagus anteriorly with sutures of right and left crura behind.	Pleuritic reaction in right chest with friction rub P.O. urinary retention due to prostate enlargement.	No recurrence. Symp- tom free.

DISPLACEMENT OF ESOPHAGUS

that the cases presented represent the efforts of several surgeons, it is surprising that a large number of patients escaped additional complications.

One patient (Case 3, Table I, Figure 5) was explored through the right thorax. The differential diagnosis between a pleuro-peritoneal hiatus hernia and esophageal hiatus hernia could not be made preoperatively. Although a satisfactory repair was obtained, in retrospect, the left thoracic approach would have allowed the operative procedure to have been performed with greater ease.

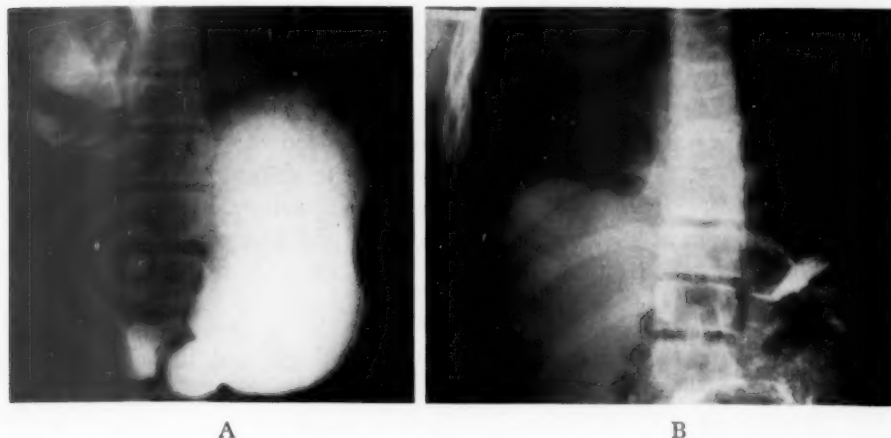


FIG. 5.—Case No. 3. U. H. No. 750827; A.—(1/19/45) Preoperative films.

B.—(3/13/45) Postoperative films, the stomach is in its normal position, the stomach empties well.

This patient was a problem in diagnosis as well as therapy. He was explored through the right thorax because the possibility of a pleuro-peritoneal hernia was considered strongly. The repair as previously described (See text) was carried out with great difficulty because of the interposition of the inferior vena cava and the necessity of working around a "corner." In retrospect, if the diagnosis of esophageal hiatus hernia could have been definitely established preoperatively, the operative repair would have been facilitated by a left transthoracic approach.

The combined abdomino-thoracic approach undoubtedly allows the operator a perfect exposure of the involved area as well as the best opportunity for a satisfactory anatomical repair. However, the disadvantage of this incision relates itself to the complicated and time consuming closure of the operative wound as well as the possibility of a chondritis should a wound infection ensue.

If in addition to the hiatus hernia, there are known abdominal lesions present the trans-abdominal or a combined abdomino-thoracic approach is to be preferred. The type of repair described herein can be accomplished satisfactorily as exemplified by the four cases approached in this manner.

In the event that one is unable to ascribe all the symptoms present to the hiatus hernia, one should deal surgically at the same sitting with the other intra-abdominal organs involved in a disease process. Anemia is not an infrequent accompaniment of hiatus hernia. Cases with anemia in the presence of occult blood in the stools without a lesion demonstrable by roentgen-ray study,

have been explored trans-thoracically. In our experience, following hernioplasty, the occult blood in the stool has disappeared and the anemia has been corrected in a short period of time. This suggests that these findings are an accompaniment of the disturbed anatomic position of the stomach.

The transabdominal approach avoids certain of the hazards of the thoracic approach. Certainly unanticipated abdominal findings can be dealt with more adequately through the abdomen. One must constantly be aware of the circumstance that the hiatus hernia may prove to be a mere incident to a more serious pathologic state.

Whereas the pleura reacts to trauma with a serous effusion which when infected may result in a total empyema, the abdomen responds to injury with a plastic exudate. Therefore, the dangers of a secondary infection in the abdomen cannot be compared to those which exist when such a complication occurs in the chest. Each case must be individualized and the approach to be made should depend upon the evaluation of the different factors present. Where the approach is optional, undoubtedly the transthoracic approach offers the operator the most satisfactory exposure and the best opportunity to perform a good anatomic repair.

SUMMARY

Certain aspects of the incidence, symptomatology, and the diagnosis of esophageal hiatus hernia have been discussed briefly.

A variation of the conventional method of repair of hiatus hernia of the diaphragm has been described. This method of repair now is used in this clinic to the exclusion of all others. This hernioplasty can be effected with ease either trans-thoracically or trans-abdominally, or by a combined approach. Thirteen cases (9 transthoracic; 3 transabdominal; 1 trans-abdomino-thoracic) have been presented in which this type of repair was used. No recurrence has been observed. Certain advantages and disadvantages of the various approaches have been reviewed.

The transthoracic approach is to be preferred. However, in cases in which a co-existent surgical disease is present in the abdomen, one should utilize the abdominal or combined approach.

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SIGMOIDOCUTANEOUS FISTULAE RESULTING FROM DIVERTICULITIS OF THE SIGMOID COLON*†

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SOME OF THE MOST DIFFICULT surgical problems encountered within the abdomen are those resulting from diverticulitis of the colon. Diverticulitis is among the commonest causes of sigmoidocutaneous fistulae, which frequently are very distressing to the patient and surgeon. It can be expected that the frequency of this complication of diverticulitis will be less in the future than it has been in the past, because recent therapeutic advances render operations on the colon less hazardous. The present study consisted of a clinical and pathologic investigation of a number of cases of diverticulitis of the sigmoid colon complicated by the occurrence of sigmoidocutaneous fistulae.

HISTORICAL BACKGROUND

Though an external fistula is not a rare complication of sigmoidal diverticulitis, not a great deal has been written about this type of lesion. Since the bladder and sigmoid are so closely approximated, it seems logical that fistulae of the bladder would outnumber the external variety. Johnson stated in 1944 that of all fistulae occurring in association with diverticulitis, those of the bladder were the most common.

Mayo, Wilson and Giffin in 1907, in one of the earliest reports on diverticulitis in which they presented a study of five proved and four probable cases of diverticulitis, had two patients in the probable group who had external fecal fistulae. In both patients the fistulae followed surgical operations. One of the patients had a sigmoidovesical fistula also. Mayo in 1918 noted that the abdominal wall was very rarely perforated as a result of an infectious process. Such a condition, however, accounted for a small percentage of the cases in which fistulae occurred in the lower part of the abdomen secondary to diverticulitis. Many of these fistulae healed spontaneously with the passing of time, he found. Sutton in 1921 stated that one encounters sigmoidovesical fistulae more frequently than those between the sigmoid and small bowel or sigmoid and skin. David in 1929 reported two cases of sigmoidovesical fistula in which external fistulae also developed after surgical drainage of abscesses. Rankin and Gorder

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studied 264 consecutive fecal fistulae at the Mayo Clinic and found 22, or 8.3 per cent, to be due to diverticulitis. Lewis and Penick in 1933 discussed 129 fecal fistulae seen at the Johns Hopkins Hospital from 1892 to 1931, only one of which was the result of diverticulitis; this fistula followed surgical drainage of an abscess, and it closed spontaneously within a short time. Jones^{7, 8} in 1936 and 1938 advocated that resection be done after the acute inflammatory process had subsided. Fistulectomy usually was contraindicated, in his opinion. In 1939, Dixon noted that when drainage of an abscess in perforative diverticulitis was necessary, a fistula frequently resulted. Some of these healed spontaneously. If such did not occur, colostomy was done proximal to the diseased segment of bowel. If the fistula persisted, closure of the fistula or segmental resection of the bowel was indicated, depending on the extent of the diverticulitis. Ginzburg in 1940 found that two of 62 external fecal fistulae studied by him were caused by diverticulitis.

Schlicke and Dixon in 1940 classified acquired external fecal fistulae according to their etiology as pathologic, traumatic and postoperative. According to them, diverticulitis and carcinoma were the common causes in the pathologic group. Since fistulae due to diverticulitis tend to heal spontaneously and since surgical operation to effect closure in such cases carries a mortality rate estimated at between 8.9 and 49 per cent, they advised that conservative therapeutic measures be given a fair trial for several months. At operation the fistulous tract was dissected and excised and the opening in the bowel was closed by intraperitoneal or extraperitoneal methods. Short-circuiting operations or resection of the bowel were at times necessary.

Mayo and Schlicke in 1941 reviewed the records of 155 cases of external fecal fistula encountered at the Mayo Clinic in the five-year period, 1930 through 1934. Nine of the fistulae resulted from diverticulitis. Six patients were operated on with a mortality rate of 16.7 per cent. Treatment, they believed, should be nonsurgical for several months in order to give the fistula adequate chance to heal spontaneously. Mora in 1944 noted that in diverticulitis, fistulae of the anterior abdominal wall always followed spontaneous rupture or surgical drainage of an abscess and that the fistulae frequently closed spontaneously. He expressed a belief that if such did not occur, colostomy should be performed. If they still persisted, excision of the fistulae and resection of the bowel was recommended.

In 1944 Lichtman and McDonald reported on 590 fecal fistulae seen at the clinic from 1930 to 1941. In 408 of these cases operation was performed. Diverticulitis was the underlying lesion in 28, or 6.8 per cent, of the cases. There was recurrence of the fistula after attempted repair in 31 per cent of the cases of diverticulitis. They found that fistulae failed to heal spontaneously because of active disease in the bowel, the presence of foreign bodies, such as cotton fibers and magnesium silicate, or the large size of the fistulous opening in the bowel. Dixon and Benson in 1946 reported a series of 65 consecutive patients with external fecal fistulae who were operated on by Dixon in the three-year period from January, 1942, through December, 1944. In 12, or 18.4

per cent, the fistula was due to diverticulitis. They advised that in perforative diverticulitis with formation of fistula, a preliminary transverse colostomy should precede any attempt at resection by at least three to twelve months.

MATERIALS AND METHODS

Forty-six cases of diverticulitis of the sigmoid colon in which there were bladder or cutaneous fistulae and in which a segment of colon had been removed surgically at the clinic were used for this study. This discussion concerns only 17 cases in which sigmoidocutaneous fistulae occurred. The cases of sigmoidovesical fistulae are being reported elsewhere. The clinical record of each case was carefully reviewed and abstracted on a specially prepared card. The surgically removed tissues which had been fixed and preserved in formalin solution were examined grossly and roughly sketched. Each specimen was sectioned, and blocks of tissue were removed from selected parts for microscopic study. The blocks of tissue were fixed in paraffin and cut; the sections were mounted on slides and stained with hematoxylin and eosin. The sections were studied microscopically, and the changes in the various layers of the wall of the bowel were observed and recorded.

Originally, the clinical records in 25 cases were abstracted, but those in which only colostomy or repair of a fistula was done and no tissue was available for study were excluded from this series. In some instances the surgically removed tissue was not suitable for study. Consequently, this was not a study of 17 consecutive cases of diverticulitis with sigmoidocutaneous fistulae.

The original plan was to study more in detail the fistulous tracts, but in most specimens no tract could be identified. Therefore, in most instances the excised segment of bowel was all that was available for study.

PATHOLOGIC FINDINGS

In each of the 17 cases studied, there was a sigmoidocutaneous fistula. Three of these patients had coexisting enterocolic fistulae, and three had sigmoidovesical fistulae. The length of the excised segment of colon averaged 14 cm. for the 17 cases. Characteristically, the involved segment of colon was thickened and rigid and contained multiple diverticula. Areas of abscess formation, granulation tissue, necrosis, and perforation were seen. Fistulous tracts were identified. Microscopically, mucosal ulceration was observed. In areas the entire bowel wall was replaced by a chronic proliferative inflammatory process characterized by the presence of dense fibrous connective tissue, lymphocytes and plasma cells. Frequently, a foreign body granulomatous type of reaction with large, multinucleated giant cells was seen (Fig. 1a.) Other features were abscesses, hyalinization of muscle and occasionally hypertrophy of the myenteric plexus. The fistulous tracts were lined by inflammatory granulation tissue (Fig. 1b.) except occasionally where a long diverticulum formed a portion of the tract. Generally the pattern of the tract conformed to that described by Lichtman and McDonald in 1944.

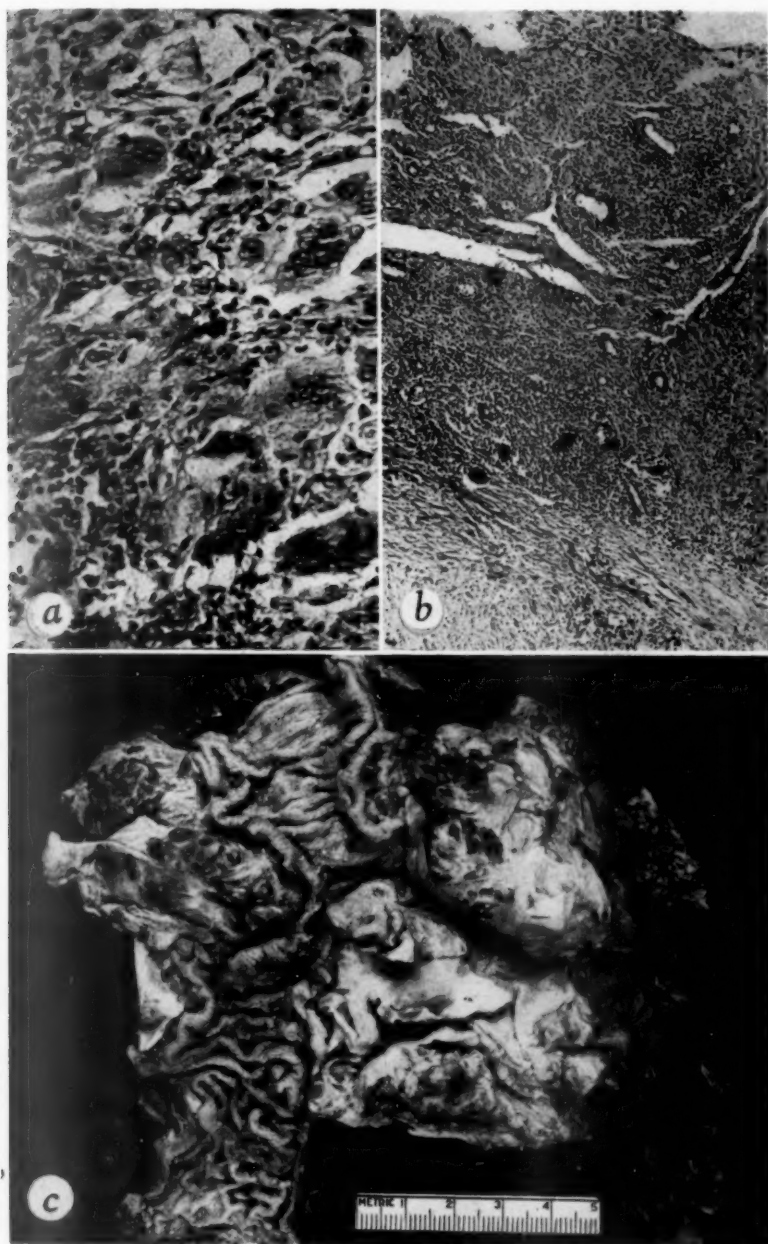


FIG. 1a.—A foreign body type of granulomatous reaction in perforative sigmoidal diverticulitis (hematoxylin and eosin, x 170).
b.—The wall of a sigmoidocutaneous fistulous tract. All tracts had essentially the same appearance (hematoxylin and eosin, x 42).
c.—A sigmoidocutaneous fistula.

CLINICAL DATA

Sex and age.—Twelve of the 17 patients in this group were males. The youngest patient was 27 years old and the oldest 60. The average age was 46.3 years.

Symptoms.—All these patients had fistulae which at times drained feces, gas and pus. Pain was the most common symptom and was located in the lower left or midpart of the abdomen usually. Approximately half the patients had had recurrent episodes of chills or fever or both. Commonly, the pain and fever recurred when the fistula closed spontaneously, but relief was afforded when the tract drained again. Constipation was a frequent complaint, but diarrhea was not complained of by any of the patients. In none of the cases was obstruction of the bowel of any clinical significance.

Previous surgical treatment.—Fourteen of these patients at some time had had an acute suppurative process within the abdomen, and in each case a sigmoidocutaneous fistula followed surgical drainage of the suppurative lesion. In the other three cases the fistula had followed surgical intervention for the correction of sigmoidovesical fistula. In one of these operation had been performed at the clinic three years previously. Also, in one of these three cases segmental resection of the colon had been done while in the other two, repair of the fistula had been done. In two instances attempts to repair the sigmoidocutaneous fistula were unsuccessful. Exploratory laparotomy was performed in two instances, and in one colostomy and subsequent closure of the colic stoma were done.

Physical findings.—In each case the cutaneous opening of the fistula was in the abdominal wall. There was a single opening in 14 of the cases and multiple openings in three. The location in each case was determined by the site of the surgical incisions. In only two instances was there a palpable mass within the abdomen, and one of these masses could be felt through the rectum. If these patients had been seen during the acute stage of the disease, probably all would have had a palpable mass.

Roentgenologic examination of the colon was done in 15 cases preoperatively. In 14 of these a diagnosis of diverticulitis or diverticulosis or both was made. In one instance the lumen of the bowel was obstructed. Fistulous tracts could be seen arising from the sigmoid frequently. In 14 instances proctosigmoidoscopic examination was done. Decrease in the mobility of the bowel was the most common finding, being present in over half the cases. Diverticula were seen in two. In four cases the bowel appeared normal.

Associated fistulae.—Six of these patients also had coexisting internal fistulae. Three had enterocolic fistulae and three had sigmoidovesical fistulae. An enterocolic fistula was suspected when food passed rapidly through the intestinal tract. The diagnosis was established by means of roentgenologic examination of the colon with the aid of barium, and in one instance the communication was found at surgical exploration when it had not been suspected previously.

Surgical treatment at the clinic.—Eighteen segmental resections of the

colon were done for sigmoidocutaneous fistulae in 17 patients with diverticulitis. An extraperitoneal type of resection was done in 12, or two thirds of the cases. Six of these had a preliminary colostomy. Resection with primary end-to-end anastomosis was done in six, or one third of the cases. Of these, five had a preliminary colostomy. The shortest interval of time elapsing between the performance of the colostomy and resection was 1.5 months, and the longest interval was 11 months. The average interval was 7.1 months. Fistulectomy was done three times in two cases.

Result of treatment.—There were no postoperative deaths. Sixteen of the 17 patients were cured of their cutaneous fistulae. Reoperation was necessary in three patients since a fistula persisted after the initial procedure. An extraperitoneal resection was followed once by the occurrence of a cutaneous fistula which closed spontaneously after a second colostomy and subsequent closure of the colic stoma. A fistulectomy was done twice in one case. The fistula persisted. The patient was cured by a resection and remained well. In the third case in which reoperation was necessary, a fistulectomy and two segmental resections of the bowel were done before all the fistulae were closed. One patient still had a sigmoidocutaneous fistula after segmental resection. Only one patient was left with a permanent colic stoma.

COMMENT

Diverticula of the colon occur most commonly in people above 40 years of age. Males are affected more often than females, the ratio being about 3:2. The pelvic colon is most often the site of involvement, and by far the majority of complications resulting from diverticula occur in the sigmoid. It is not the purpose of this paper to discuss the controversial points regarding the etiology of diverticula. It is the opinion of most authorities that diverticula form as the result of several factors, the most important of which is increased intraluminal pressure plus weakness in the musculature of the bowel wall produced by the penetration of the wall by blood vessels and possibly fat.

The wall of a diverticulum is composed of atrophic mucosa, submucosa and serosa. Not infrequently, a thin layer of muscle is present, especially near the proximal end of the sac. Fecal concretions which are contained within these sacs cause mucosal erosion and irritation, permitting bacterial invasion of the wall of the sac. The inflammatory process initiated by the invading bacteria and toxins occludes the mouth of the diverticulum and produces necrosis and extension of the process into the adjacent wall of the bowel. The severity of the inflammation depends upon the virulence of the organism and resistance of the patient.

If the process spreads rapidly, there is necrosis of the diverticulum and wall of the bowel, perforation and abscess formation. The abscess may attach itself to the abdominal wall, bladder or other viscus and erode through the wall of the viscus, producing a fistula. More commonly, the process spreads more slowly. The bowel wall and the mesentery then become involved in a chronic proliferative extramucosal inflammatory process which Wilson¹³ in 1907 called "peri-

diverticulitis." This is the most important pathologic condition resulting from diverticula. The involved loops of bowel become attached to the abdominal wall or viscera, and abscesses form within the inflammatory mass from time to time and drain through the path of least resistance. Frequently, this path of drainage is into the colon, but not infrequently it is into the bladder, small bowel or abdominal wall. This seems to be the mechanism at work in most of the cases in this group.

In at least four cases a long perforated diverticulum was attached to the abdominal wall and formed an abscess which was drained, leaving a suppurative saccular sigmoidocutaneous fecal fistula (Fig. 1c) as described by Lichtman and McDonald in 1944. The proximal part of the fistula was composed of the diverticulum itself; the distal portion was a tract lined with fibrous granulation tissue and connecting the two was an abscess cavity. However, in most instances the bowel had become densely adherent to the abdominal wall and the communication had occurred through the inflammatory mass.

Diverticulitis is an important but not the most common cause of external fecal fistulae. Ginzburg showed that diverticulitis accounted for 3.2 per cent of external fecal fistulae. Lichtman and McDonald found diverticulitis to be the underlying cause in 6.8 per cent of their cases. Dixon and Benson reported diverticulitis to be the cause in 18.4 per cent.

When the patients in our series were first seen at the clinic symptoms had been present, on the average, for 46.1 months and the fecal fistula had been present an average of 17.1 months. Thus it is seen that the symptoms of diverticulitis had been present an average of 29 months when the fistula developed. The fact that 14 of these 17 patients had had surgical drainage of an acute suppurative process within the abdomen is evidence that the formation of a fistula in diverticulitis is preceded by the formation of an abscess in most instances. Acute perforation of a solitary diverticulum has been discussed by many authorities, but such is not the usual mechanism of the formation of a fistula. Surgical trauma is a contributing factor in many cases. Not all external fecal fistulae caused by diverticulitis have their openings in the anterior abdominal wall. They may open in the lumbar region, buttocks, thigh, perineum, thorax or perianal region. In the present group, all openings occurred in the abdomen, with most of them located in the lower midline or to the left of it. In none of these cases could the opening into the sigmoid be visualized on proctosigmoidoscopic examination.

To determine the underlying cause and the part of bowel from which an external fistula arises is at times a difficult task. The history and physical examination are helpful, but the most valuable information is afforded by roentgenologic examination of the colon. In the present group, a diagnosis of diverticulitis or diverticulosis or both was made in all cases except one in which the lumen of the bowel was obstructed. In almost half the cases a fistulous tract could be seen to arise from the sigmoid. In some instances roentgenologic examination after the injection of iodized oil into the tract revealed the site of origin of the fistula.

As shown by Mayo and Schlicke, and by Rankin, Barga and Buie, the basic lesions from which fecal fistulae result are numerous. The commoner ones which must be considered in the differential diagnosis are appendiceal disease, regional enteritis, tubo-ovarian inflammatory disease, pelvic or intestinal tuberculosis, malignant tumors of the pelvis or bowel, ulcerative colitis, actinomycosis, traumatic perforation of the bowel and foreign body. Fecal fistula may follow various intra-abdominal operations.

As emphasized by Jones,⁸ Mayo and Schlicke, and Dixon and Benson, external fecal fistulae resulting from diverticulitis tend to heal spontaneously, and ample time, perhaps a year, should be allowed for healing to occur before surgical measures for correction are employed. Fourteen of the 17 patients in our series had had their fistulae a year or longer before they were treated surgically at the clinic. The other three were operated on two, five and seven months respectively after development of the fistulae.

For the correction of sigmoidocutaneous fistulae that result from diverticulitis, any surgical procedure less radical than segmental resection of the diseased bowel usually fails. This has been emphasized by various authorities. Dixon and Benson expressed the belief that a preliminary colostomy should precede resection by three to 12 months, while Babcock (1945) has followed the practice of doing a resection and primary anastomosis without colostomy. It would seem that the type of procedure chosen should depend entirely upon the conditions presented in the individual case. Usually it is safer to establish a preliminary transverse colic stoma and after an interval of a few months to carry out a resection and end-to-end anastomosis or an extraperitoneal resection, subsequently closing the colic stoma. However, at times in perforative diverticulitis, it seems advisable to do a primary resection and end-to-end anastomosis with or without simultaneous transverse colostomy.

Eleven of the 17 patients were prepared preoperatively with the aid of succinylsulfathiazole (sulfasuxidine), and in most instances one of the sulfonamides was used intraperitoneally.

SUMMARY AND CONCLUSIONS

A review of the literature on diverticulitis with sigmoidocutaneous fistulae has been presented. According to various investigators diverticulitis accounts for 3.2 to 18.4 per cent of the external fecal fistulae. Our work was based upon 17 cases of sigmoidocutaneous fistula due to diverticulitis of the sigmoid colon. In each case a segmental resection of the colon was done at the Mayo Clinic. Characteristically, the excised segment of the colon presented many diverticula. The wall of the bowel was involved in a chronic extramucosal proliferative inflammatory process. Commonly, areas of necrosis, abscess formation and perforation were seen. As with colonic diverticula, fistulae were more common in older than in younger men.

The symptoms of sigmoidocutaneous fistula were the presence of the fistulae, abdominal pain, constipation and chills and fever. Each fistula followed some type of surgical operation, usually incision and drainage for an acute suppur-

ative process within the abdomen. These patients had had symptoms suggestive of diverticulitis for an average of approximately 2.5 years when their fistulae developed. The fistulae had been present for an average of approximately 1.5 years when the patients came to the clinic. Roentgenologic examination of the colon was the most important aid in diagnosis and differential diagnosis. Other types of internal fistulae were present in about one-third of the cases.

Fistulae of this type tend to close spontaneously and should be allowed ample time, approximately 12 months, to do so. When surgical treatment is carried out, excision of the diseased segment of colon should be done and should usually be preceded by a temporary transverse colostomy made six months prior to resection. The choice of procedure should depend on the conditions present in the individual case. In this group of 17 patients with sigmoidocutaneous fistulae there were 18 segmental resections of the colon with no operative deaths. Sixteen patients were relieved of their external fecal fistulae.

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A NEUROGENIC FACTOR IN EXPERIMENTAL TRAUMATIC SHOCK: A SUMMARY OF RECENT STUDIES INCLUDING OBSERVATIONS ON PROCAINIZED AND SPINAL DOGS*†

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THE PURPOSE OF THE PRESENT REPORT is to correlate and integrate a series of investigations carried out between 1942 and 1947 to determine the role of the afferent nervous factor in experimental traumatic shock.

During World War I, it was found that in a group of 27 soldiers suffering from wound shock,¹ the total blood volume was reduced, and that the reduction in volume bore a definite relation to the severity of the clinical state of the patient. The question that remained to be answered is whether or not, in these forms of shock, the complete traumatic syndrome can always be accounted for by the loss of circulating blood volume alone. The investigations to be described were undertaken to elucidate this point.

Cannon and Bayliss² were the first group of investigators to estimate the loss of fluid into an injured part after traumatizing the muscles of one thigh of the cat. They determined the amount of bleeding by removing the two hind limbs by symmetrical cuts across the thighs and weighing them. They stated that there was not sufficient bleeding into the wounds to account for the effects observed. Again, in a later series of experiments, Cannon³ found that in some cases the difference in weight of the two sides was as low as 11 per cent of the estimated weight of the total blood of the animal and concluded that the development of the low blood pressure after tissue injury was proved not to be due to fluid loss from the systemic circulation. In 1930, Blalock⁴ and Parsons and Phemister⁵ repeated the observation on dogs with amputation in the mid-abdominal region instead of across the thighs. The difference in weight between the two halves was found to vary from 4.2 to 8.0 per cent of the body weight with an average of 5.1 per cent in a group of eight dogs reported by Blalock, and from 4.2 to 6.0 per cent with an average of 5.3 per cent in the series of six dogs reported by Parsons and Phemister. These results indicate that severe muscle trauma to a thigh results in some bleeding and accumulation of fluid in the loose tissue of the groin and flank, which is not included in the amputated parts if the incision is made across the upper edge of the thigh. The evidence advanced by these investigators suggests further that in *severe* muscle

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trauma the local loss of blood and fluid may be sufficient of itself to precipitate fatal shock. Unfortunately, they made no direct measurements of blood volume changes. Furthermore, these experiments were carried out on anesthetized animals, in which all compensatory mechanisms in response to injury and blood loss are modified to a considerable extent.^{6, 7} At any rate, the important question which remained unanswered is whether or not the amount of bleeding incidental to a *moderate* degree of muscle trauma is also adequate to account for the ensuing fatal syndrome.

Actual determination of the reduction of blood volume in various types of shock has been made by a number of workers.^{1, 8} But the methods have not been of sufficient accuracy to permit a quantitative study of blood loss in traumatic shock. Recently, Gregersen and his associates made a careful study of the dye (T-1824) dilution method in normal, hemorrhaged and traumatized dogs⁹ as well as in the human patients.^{10, 11} They found that the blood volume

TABLE I.—Data on dogs with blood volume reduction as a result of (a) simple hemorrhage, (b) muscle trauma, (c) sublethal hemorrhage plus sciatic stimulation, and (d) muscle trauma and chronic deafferentation (abstracted from Wang, et al.^{14, 28, 42}).

	Hemorrhage	Muscle Trauma	Hemorrhage Plus Stimulation	Deafferentation and Trauma
Control blood volume (cc./kg.).....	97.9 ± 1.3	100.7 ± 1.5	96.7 ± 1.5	99.1 ± 1.5
Residual blood volume at 50% mortality..	59.1 ± 2.9	73.4 ± 3.0	69.0 ± 2.5	64.7 ± 1.8
Percentage survival at 66 cc./kg. residual volume.....	76 ± 8.7	25 ± 8.3	37 ± 9.5	59 ± 10.8

determined with the dye method checked within 5 per cent of the value obtained with the improved CO method.¹² Using this standardized dye dilution method, Wang, et al.^{13, 14} compared the effects of reducing the circulating blood volumes in dogs by simple hemorrhage or by muscle trauma. They reported a striking difference in the ability of these two groups of animals to withstand a specific loss of blood. In dogs in which the blood volume is reduced to 66 cc. per kg. by simple hemorrhage the percentage survival is 76 ± 8.7 per cent; if, on the other hand, a similar reduction is effected by muscle trauma, the chance of survival is only 25 ± 8.3 per cent (summarized in Table I). Hemorrhaged animals have a 50 per cent mortality if the blood volume is reduced to 59.1 ± 2.9 cc. per kg., whereas in muscle trauma the same chance of survival prevails when the residual volume is 73.4 ± 3.0 cc. per kg.* This difference in the ability of the two groups of animals to withstand blood loss could not be ascribed to the constant leakage of blood and fluid into the injured area since the blood volume remains fairly constant throughout the period of observation.⁹ Indeed, if water is given to the animals six hours after trauma, the total circulating volume on the following day is not significantly altered from that determined two hours after injury.¹⁴ Therefore, the evidence clearly indicates

* The concept of selecting a 50 per cent mortality point and comparing the effect of the two procedures is an important one, for severe muscle trauma that produces a 100 per cent mortality may conveniently result in an extensive blood loss comparable to that observed in animals suffering from fatal hemorrhage.

EXPERIMENTAL TRAUMATIC SHOCK

that the ability of hemorrhaged dogs to withstand a critical quantity of blood loss is strikingly greater than that of dogs receiving muscle trauma. This fact was the basis for undertaking further investigation of other possible factors contributing to the high mortality rate in traumatized animals.

As illustrated in Figure 1, the traumatized animals as contrasted with hemorrhaged animals have early tachycardia exceeding 200 beats per minute, high mean blood pressure, high hematocrit values, and early depression of the central nervous system. They also showed high calculated peripheral resistance¹⁵ and prolonged fluorescein circulation time.¹⁶ These differences suggest

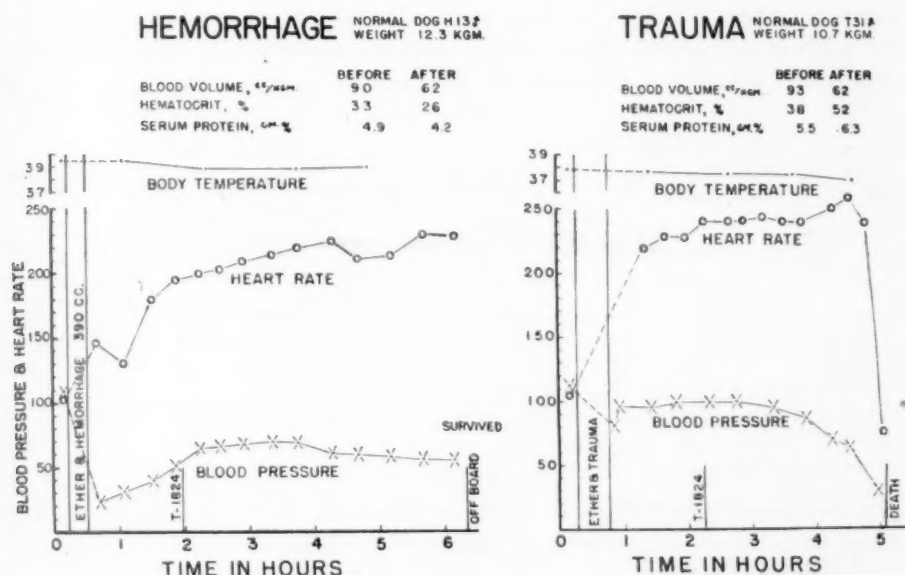


FIG. 1.—Comparison of the clinical manifestations in a typically hemorrhaged animal (dog H 13) and a typically traumatized animal (dog T 31). Note the characteristic slowly increasing tachycardia and low mean blood pressure level in the hemorrhaged animal which survived. The traumatized animal, despite its high (nearly normal) blood pressure level, died after 4 hours (from Wang, *et al.*¹⁴).

that the sympathetic nervous system is intensely active in traumatic shock. The question arises as to whether or not intense sympathetic activity can be initiated by afferent impulses from the injured areas.

Slome and O'Shaughnessy¹⁷ have shown that shock can be produced in the cat by appropriate trauma to the perfused limb separated completely from the general circulation and communicating with the body only by means of its nerves. Such a finding, though confirmed by Lorber, Kabat and Welte,¹⁸ is not substantiated by Bell, Clark and Cuthbertson,¹⁹ nor by Blalock and Cressman.²⁰ In any case, it is difficult to evaluate this type of experiment because it must be done under deep narcosis. On the other hand, a number of investigators^{21, 22, 23, 24} have stimulated the sciatic or other somatic afferent nerves in unsuccessful attempts to produce a depression of blood pressure and shock.

Recently, Phemister and his associates^{25, 26} stimulated the sciatic nerves in rabbits under urethane and in dogs under sodium barbital and obtained only pressor responses.

Statistical evaluation of the quantitative data on uncomplicated hemorrhage¹⁴ enabled this laboratory to ascertain the ability of animals to withstand hemorrhage and thus to carry out a series of sublethal hemorrhage experiments coupled with continuous electrical stimulation of the sciatic nerves.^{27, 28} The stimulation was started immediately after hemorrhage while the animals were still under the residual effects of ether anesthesia. The mean blood pressure showed a large increase at first which is probably related to struggling. Within a minute or two, the blood pressure returned to a level 25 to 35 mm. Hg above the reading taken immediately before stimulus was applied. The heart rates were maintained over 200 beats per minute. In most instances these effects

TABLE II.—Comparison of changes in hematocrit values and plasma protein concentrations in dogs following (a) simple hemorrhage, (b) muscle trauma, (c) sublethal hemorrhage plus sciatic stimulation, and (d) muscle trauma and chronic deafferentation (abstracted from Wang, et al.^{14, 28, 42}).

	Hemorrhage		Muscle Trauma		Hemorrhage Plus Stimulation		Deafferentation and Trauma	
	Hct. %	Protein Gm.%	Hct. %	Protein Gm.%	Hct. %	Protein Gm.%	Hct. %	Protein Gm.%
Control values.....	41.9	5.8	42.9	5.8	44.7	5.7	40.5	6.1
s. e.....	1.1	0.1	0.9	0.1	1.0	0.1	0.9	0.1
Changes after injury.....	-4.8	-0.9	4.1	0.0	-1.7	-0.5	1.7	-0.5
s. e.....	0.8	0.06	0.9	0.07	0.7	0.05	0.7	0.05

persisted, for if the stimulus was suddenly discontinued at any time during the experiment both blood pressure and heart rate slowly decreased. In this series of experiments with sublethal hemorrhage plus stimulation, the average quantity of blood removed is 33 cc. per kg., which is considerably smaller than that in the simple hemorrhage series (40 cc. per kg.); and the residual blood volume at the 50 per cent mortality point is 69.0 ± 2.5 cc. per kg., which is significantly higher than the corresponding value in the simple hemorrhage series (59.1 ± 2.9 cc. per kg.; see Table I). The percentage survival at a residual volume of 66 cc. per kg. in this series (37 ± 9.5 per cent) is also significantly different from that in the simple hemorrhage series (76 ± 8.7 per cent). Thus, it is apparent, that at any given blood volume reduction, the ability of the animal suffering simple hemorrhage to survive is significantly greater than either (a) the dog suffering muscle trauma or (b) the dog suffering a sublethal hemorrhage and afferent nerve stimulation.

The data indicate clearly that strong sciatic stimulation plays an important role in elevating the mortality rate in animals with reduced blood volume. However, in normal animals electrical stimulation of the sciatic nerves has little effect; certainly it alone will not produce shock. Indeed, we have not been able by afferent nerve stimulation to put any dog with a residual blood volume over 75 cc. per kg. into fatal shock.

EXPERIMENTAL TRAUMATIC SHOCK

The clinical signs observed in the animals of the nerve stimulation series were similar to those shown by traumatized animals: early tachycardia (over 200 beats per minute), relatively high mean blood pressure, early central nervous system depression and sudden death with a sharp decline of blood pressure (Fig. 2). It may appear paradoxical that increased blood pressure following sciatic stimulation exerts a deleterious effect upon the condition of the hemorrhaged animal. Indeed, in our experience the animals that give the most marked sciatic pressor responses are those that show an early depression of the central nervous system and death. In an animal with an already reduced blood volume, the cardiac output is decreased and the tissues anoxic. If, through sciatic stimulation, the vessels are further constricted despite the resulting high blood pressure, there will be a further reduction of peripheral blood flow, tissue damage and death. The failure of previous workers to produce shock by afferent nerve stimulation can be accounted for by the following facts, that they (a) used anesthetized animals in which the metabolism and vasomotor reflexes are depressed, (b) did not use animals with a slightly reduced blood volume, and (c) expected an immediate depressor response following electrical stimulation of the somatic afferent nerves.

It has long been known that nearly all anesthetics depress vasomotor reflexes. In fact, as early as 1918, Wiggers²⁴ in his studies on shock remarked, "It seems probable that the potency of peripheral stimuli and trauma in producing reactions in the body leading to shock and circulatory failure depends, to a considerable extent, on how little the conducting mechanisms of the spinal cord and brain are depressed by the anesthetic." And yet all investigators who attempted to produce shock by stimulation of the afferent nerves have given various anesthetics to the animals, perhaps in the belief that unanesthetized animals would be unmanageable if the afferent nerves were stimulated. In our

HEMORRHAGE NORMAL DOG S21P WEIGHT 9.0 KG. WITH AFFERENT NERVE STIMULATION

	BEFORE	AFTER
BLOOD VOLUME, cc/kg.	90	63
HEMATOCRIT, %	42	43
SERUM PROTEIN, gm %	6.8	6.3

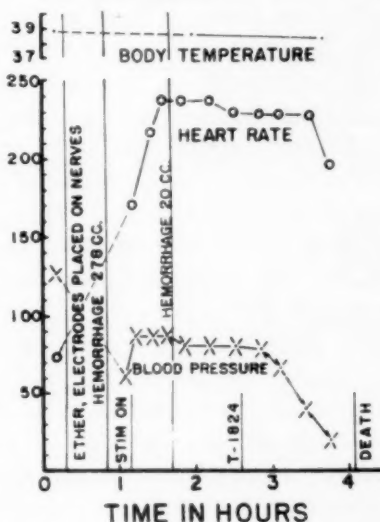


FIG. 2.—The clinical manifestations of a dog (S 21) which has been subjected to hemorrhage and stimulation. The blood volume reduction is comparable with that in dog H 13 and dog T 31. Note the effect of stimulation of the sciatic nerves on the heart rate and mean blood pressure. This figure demonstrates the similarities between this dog and the traumatized dog (T 31) in early tachycardia exceeding 200 beats per minute, high level of mean blood pressure and death with a rapid decline of the pressure (from Overman and Wang²⁸).

experience, except for initial struggling, the animals remained quiet, though the effect of reflex nociception was clearly maintained. Expressions of pain could easily be obtained again if the stimulus were reinstituted after being briefly discontinued. In view of the fact that pain receptors are believed to be slow adapting,²⁹ the early disappearance of this sensation in these animals must be presumed to be central. In this connection, it is interesting to note that severe wounds in soldiers are often associated with little pain, even though they are not in shock at the time.³⁰

Investigators have not previously attempted to produce shock by combining hemorrhage and somatic afferent nerve stimulation. One of the difficulties has been the failure to recognize that even an important contributing nervous factor to the development of shock might not alone be expected to produce a fatal outcome. It is, however, well known that fluid loss, important as it is, may not alone produce fatal shock. Once this fact is recognized, the production of shock becomes a quantitative matter and the precipitating factors may well be present, each alone in sublethal quantity; the algebraic sum being sufficiently deleterious to lead to death. A second difficulty faced by previous investigators has been in the estimation of the degree of hemorrhage which is sublethal. It is interesting that Mann²³ has said, "It is impossible to reduce the anesthetized animal to a state of shock by any degree of sensory stimulation provided all hemorrhage is prevented . . .". Phemister and his associates²⁵ hemorrhaged animals to shock levels of blood pressure and then superimposed a further fall of blood pressure by aortic depressor nerve stimulation. They likewise stimulated the sciatic nerves in anesthetized rabbits and dogs, and failed to obtain a fall in blood pressure throughout a period of one or more hours of stimulation. Having failed to find the anticipated depressor response to sciatic stimulation, they did not proceed to combine stimulation and hemorrhage.

Recently Trueta, *et al.*^{31, 32} reported a diversion of the intra-renal blood flow from the cortex to the medulla, with a subsequent variable cortical ischemia, as a result of hemorrhage, muscle trauma, or stimulation of the central end of the divided sciatic nerve. This information is interesting because it shows that sciatic stimulation may produce a change in renal circulation identical to that produced by hemorrhage or muscle trauma. Further, the resulting ischemic kidney tissue might contribute one or more chemical factors in addition to the nervous pressor effect of somatic afferent stimulation.³³ However, the importance of these newly discovered phenomena in the shock syndrome has yet to be ascertained.

Although afferent nerve stimulation in sublethally hemorrhaged dogs produces alterations in mortality rate and in the clinical signs of shock which bring such animals into close resemblance with traumatized dogs, these experiments are open to certain criticisms. First, exposure of the sciatic nerves entails a certain amount of trauma and secondly, electrical stimulation is a highly artificial stimulus. Therefore, it is pertinent to make as a corollary the following observation, *i.e.*, the effect of deafferentation on the course of traumatic shock to show if traumatized deafferent animals have a mortality rate

EXPERIMENTAL TRAUMATIC SHOCK

and a clinical shock syndrome similar to hemorrhaged animals. Many workers have attempted to interrupt the pathways which carry nociceptive impulses centrally from the region of injury,^{34, 35, 36, 37, 38, 20} but most of them also have used general anesthesia. The results have been diversified and often conflicting. Swingle and his associates^{37, 38} have studied the effect of exclusion of the afferent impulses in traumatic shock and have reported that many deaths are prevented by local procaine anesthesia. However, one is forced to accept these results with reservations for there is no adequate objective proof that the severity of injury was exactly the same as in the control experiments. The criterion used was to traumatize the animals until the mean blood pressure was reduced to 70 mm. Hg or lower. Since the afferent impulses yield, as we believe, a reflex pressor effect instead of a depressor response, trauma given to the procainized hindlegs which results in a fall of blood pressure to 70 mm. Hg

TABLE III.—Data on traumatized dogs in which the hindlegs have been infiltrated with procaine (4 per cent solution), including changes in blood volumes, hematocrit values and plasma protein concentrations.

Dog No and Sex	Body Wt. kg.	Control			After Muscle Trauma			Change			Fate
		B.V. cc./kg.	Hct. %	Prot. Gm. %	B.V. cc./kg.	Hct. %	Prot. Gm. %	B.V. %	Hct. %	Prot. Gm. %	
P 1 ♀	10.0	126	45.0	5.8	92	46.7	6.0	27	1.7	0.2	Survived
P 2 ♂	9.4	113	55.0	5.5	85	55.0	5.4	25	0.0	-0.1	Died, 3.7 hr.
P 3 ♀	12.4	121	49.1	6.6	81	51.9	6.5	33	2.8	-0.1	Died, 6+ hr.
P 4 ♀	7.9	100	48.2	5.5	76	50.4	5.4	24	2.2	-0.1	Survived
P 5 ♂	8.8	...	...	...	75	52.0	5.5	..	...	...	Died, 6+ hr.
P 6 ♂	16.8	...	...	...	74	45.7	6.5	..	...	...	Survived
P 7 ♂	12.4	104	49.6	5.5	66	44.6	5.0	37	-5.0	-0.5	Died, 5.3 hr.
P 8 ♀	11.1	102	47.9	6.1	64	48.2	5.2	37	0.3	-0.9	Died, 5.2 hr.
P 9 ♀	11.0	94	39.0	5.7	63	38.1	5.3	33	-0.9	-0.4	Died, 2.7 hr.
P10 ♀	9.2	111	44.1	6.1	63	42.7	5.3	43	-1.4	-0.6	Died, 6+ hr.

is generally not as severe as that which results in a similar fall of blood pressure in a non-procainized animal. We have, therefore, repeated these experiments including measurement of control and residual blood volumes in an effort to standardize the degree of blood loss (Table III). The procedure involved in local procaine infiltration is simple. Furthermore, procaine is an ideal drug since in suitable doses it selectively blocks impulses in the pain fibers.³⁹ On the other hand we often experience difficulty in deciding upon the dosage to be given and it must likewise be apparent that procaine in large doses may have some undesirable side effects on the neuro-circulatory system of traumatized animals.

With these reservations in mind, a review of our series of procainized traumatized dogs reveals that although several of these animals showed less excitement during the period of incipient shock and slower heart rates compared with the untreated animals in traumatic shock, the chances of survival for these procaine-treated animals were not enhanced when the blood volume was reduced to the same extent as in the non-procainized controls.

In another series of experiments it was found that sectioning the spinal cord at the level of T_{10-12} following muscle trauma did not benefit the animals (Table IV). Swingle and co-workers³⁸ were similarly impressed by data on dogs transected just previous to the trauma procedure. In the series reported here, several animals died so soon after the transection that there was insufficient time for a second blood volume determination. It appears then that acute spinal transection is too drastic a procedure for traumatized dogs to withstand. In a third series of experiments, chronic spinal animals were used.* Again it was found that death following muscle trauma is not prevented in such preparations (Table V). The difficulty has been that spinal animals are not able to micturate adequately by themselves and are prone to develop cage sores. Consequently, most of the muscle trauma experiments were carried out in the first

TABLE IV.—Data on traumatized dogs in which the spinal cord was severed at the level of T_{11} following muscle trauma, including changes in blood volume, hematocrit values and plasma protein concentrations.

Dog No. and Sex	Body Wt. kg.	Control			After Muscle Trauma			Change			Fate
		B.V. cc./kg.	Hct. %	Prot. Gm. %	B.V. cc./kg.	Hct. %	Prot. Gm. %	B.V. %	Hct. %	Prot. Gm. %	
TS 1 ♂	11.8	99	40.8	5.9	84	50.8	6.4	15	10.0	0.5	Survived
TS 2 ♂	10.9	109	38.2	7.7	83	39.6	7.4	24	1.4	-0.3	Survived
TS 3 ♀	14.3	122	50.5	6.2	78	48.9	6.0	36	-1.6	-0.2	Died, 5.5 hr.
TS 4 ♂	16.1	100	42.6	6.4	76	37.3	5.4	24	-5.3	-1.0	Died, 2.4 hr.
TS 5 ♀	13.0	114	38.8	5.3	75	50.0	5.9	34	11.2	0.6	Survived
TS 6 ♂	13.9	84	51.2	6.2	74	62.8	6.4	12	11.6	0.2	Survived
TS 7 ♂	9.8	100	43.6	5.7	74	47.5	5.7	26	3.9	0.0	Died, 6+ hr.
TS 8 ♀	7.8	109	57.4	5.6	74	53.3	5.3	32	-4.1	-0.3	Died, 2.3 hr.
TS 9 ♂	9.0	111	36.2	6.0	74	41.8	6.3	33	5.6	0.3	Died, 2.5 hr.
TS10 ♂	8.0	93	35.1	5.3	59	35.5	5.0	37	0.4	-0.3	Died, 4.2 hr.

postoperative week during which the animals had not fully recovered from the operation, as evidenced by a decrease in body weight (Table V) and a low control blood volume in several of these dogs. Nevertheless, these animals showed a slight degree of tachycardia and low mean blood pressure, and the central nervous system was not depressed until death was clearly imminent (see Fig. 3). In other words, chronic spinal animals presented a shock syndrome following muscle trauma, which was very much like that which occurred in the normal animal with a similar reduction of blood volume by hemorrhage. However, the mortality rate of traumatized spinal animals did not differ significantly from that of traumatized normal animals.

From these series of experiments on acute and chronic cord transection,

* This series of experiments (Table V) were performed with the collaboration of Professor Walter S. Root. In several of these dogs, the lumbar sympathetic chains were extirpated approximately 2 weeks before the spinal operation in order to eliminate the visceral afferent fibers in the chains. No differences in symptomatology following muscle trauma were observed in these animals and in animals in which only the spinal cord was transected.

EXPERIMENTAL TRAUMATIC SHOCK

it may be inferred (a) that acute spinal transection is not a desirable experimental procedure to eliminate afferent impulses from the injured region in traumatic shock and (b) that animals need a longer period than a few days for recuperation from the effects of a major surgical procedure. The operation designed to meet these requirements is a complete deafferentation of both hindlegs, leaving only the three sacral dorsal roots on one side intact to preserve the function of micturition. Although the operation is much more extensive than simple transection of the spinal cord, it has definite advantages in that such animals are deprived only of afferent pathways and their postoperative course is relatively uneventful because voluntary micturition is preserved. The general condition of these animals, at the time of the traumatic procedure, was good, as indicated by the normal body weights and blood volume.*

TABLE V.—Data on chronic spinal dogs before and after trauma, including changes in blood volumes, hematocrit values and plasma protein concentrations.

Dog No. and Sex	Body Wt. kg.	Control			After Muscle Trauma			Change			Fate
		B.V. cc./kg.	Hct. %	Prot. Gm. %	B.V. cc./kg.	Hct. %	Prot. Gm. %	B.V. %	Hct. %	Prot. Gm. %	
ST 1 ♂	11.1(11.4)*	107†	47.9	5.9	87	48.4	5.9	19	0.5	0.0	Died, 5.6 hr.
ST 2 ♂	7.5(7.8)	98	52.6	6.4	84	53.6	6.5	14	1.0	0.1	Died, 3.1 hr.
ST 3 ♀	14.2(14.6)	109	53.5	6.6	82	52.8	6.0	25	-0.7	-0.6	Survived
ST 4 ♀	8.9(10.0)	111	49.1	5.7	79	43.1	5.5	29	-6.0	-0.2	Died, 3.8 hr.
ST 5 ♂	13.5(14.6)	117	45.3	6.1	73	48.2	6.0	38	2.9	-0.1	Survived
ST 6 ♂	10.7(11.3)	96	43.3	5.9	71	40.8	5.4	26	-2.5	-0.5	Died, 4.4 hr.
ST 7 ♂	11.7(12.0)	102	52.4	6.4	70	48.4	6.0	31	-4.0	-0.4	Survived
ST 8 ♂	12.6(13.1)	92	45.4	6.0	69	50.0	5.8	25	4.6	-0.2	Died, 5.0 hr.
ST 9 ♂	12.8(13.2)	94	40.9	5.8	67	39.0	5.3	29	-1.9	-0.5	Died, 2.0 hr.
ST10 ♀	10.6(10.8)	80	40.5	5.8	63	38.9	5.5	21	-1.6	-0.3	Died, 3.0 hr.
ST11 ♂	9.4(9.5)	100	37.7	5.7	63	39.4	5.5	37	1.7	-0.2	Died, 6+ hr.
ST12 ♂	13.4(14.0)	84	45.6	6.4	62	45.1	6.1	26	-0.5	-0.3	Died, 6+ hr.
ST13 ♂	12.8(13.1)	88	35.0	6.0	61	37.2	5.9	31	2.2	-0.1	Died, 6+ hr.
ST14 ♂	10.0(10.5)	94	42.3	5.9	60	42.6	5.5	36	0.3	-0.4	Died, 4.8 hr.
ST15 ♂	8.7(9.0)	79	44.3	6.4	59	44.0	6.3	25	-0.3	-0.1	Died, 2.0 hr.
ST16 ♀	9.6(10.0)	87	48.3	6.9	57	52.6	6.4	34	4.3	-0.5	Died, 4.3 hr.

* Body weight at time of spinal transection.

† The blood volume is calculated on the basis of the body weight at the time of trauma experiment.

* Phemister, *et al.*⁴⁰ have sectioned aseptically all the dorsal roots on the left side below T₁₂ in 4 dogs. They reported that these dogs tolerated trauma and blood loss in the deafferent region no better than did the normal dogs. Unfortunately, trauma experiments were performed only 4 hours to 6 days after the operation. It is also of interest to note that in 3 out of the 4 dogs, considerable hemorrhage occurred during the deafferentation operation, and that equivalent transfusion had to be given in an attempt to replace the lost blood. However, animals following extensive laminectomy for the exposure and section of all the dorsal roots of a hindlimb need relatively long period for recuperation, since our dogs, despite negligible blood loss during the operation, showed continued weight loss for the next 7 to 10 days and a return to control body weight and control blood volume did not occur until the 4th week, indicating that recovery of these animals could not be attained within a few days.

The results of the trauma experiments which were performed in the deafferent animals have been reported in detail elsewhere.^{41, 42} In brief, the residual blood volume at the 50 per cent mortality point in this series of 30 dogs is considerably reduced (64.7 ± 1.8 cc. per kg., see Table I) as compared with the value in the normal trauma series (73.4 ± 3.0 cc. per kg.). The difference between these two values is statistically significant. Also, the percentage survival at a residual volume of 66 cc. per kg. in the deafferent series (59 ± 10.8 per cent) is significantly higher than the value in

TRAUMA		DOG ST 6 F
WITH SPINAL CORD CUT AT T11		WEIGHT 10.7 KGM
	BEFORE	AFTER
BLOOD VOLUME, cc/kgm.	96	71
HEMATOCRIT, %	43	41
SERUM PROTEIN, gms	5.9	5.4

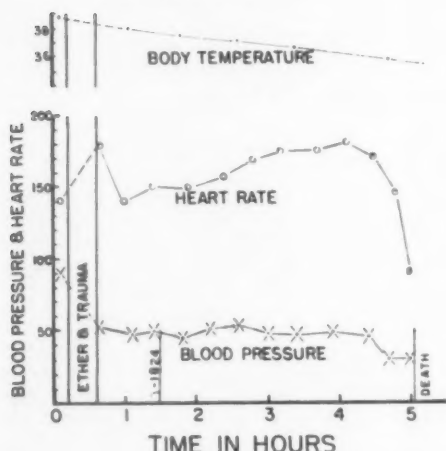


FIG. 3.—The clinical manifestations of a chronically spinal transected dog (ST 6) which has been subjected to muscle trauma 6 days after transection. This animal showed a high heart rate, a low mean blood pressure and a loss of 0.6 kg. of body weight on the day of trauma experiment. Nevertheless, following muscle trauma, it showed a slowly increasing tachycardia and low mean blood pressure, which are often observed in the hemorrhaged dogs (see dog H 13, Fig. 1). But this dog did not survive.

mean blood pressures of less than 70 mm. Hg within the first half hour following injury. Six of these survived. On the other hand, in a large series of over 100 muscle trauma experiments on normal animals accumulated in this laboratory only three dogs survived when the initial mean blood pressure was reduced below 70 mm. Hg. This suggests that the procedure of muscle contusion has two concurrent effects on the mean blood pressure level: (a) the reduction in circulating blood volume causes a reduction of the mean blood pressure; (b) the local somatic afferent impulses produce an elevation of blood pressure. In some animals the latter effect is so dominant that the blood pressure is higher

the normal trauma series (25 ± 8.3 per cent). Our data indicate clearly that animals survive muscle trauma with a greater reduction of blood volume if the afferent impulses from the injured area are interrupted by previous deafferentation. The afferent impulses from the injured region must have played an important role in bringing about the high mortality of traumatic shock in normal animals.

The clinical picture of the deafferent dogs following muscle trauma (Fig. 4), like that shown by the spinal preparation (Fig. 3), closely resembles that of simple hemorrhaged animals (Fig. 1). As a group, the deafferent dogs had a tachycardia of less than 200 beats per minute or such a heart rate was attained only some time after injury. The deafferent dogs were usually not restless, and were not depressed until immediately before death. In these animals the mean blood pressure was usually very low immediately after muscle trauma. In the series of 30 deafferent dogs, 14 had

EXPERIMENTAL TRAUMATIC SHOCK

after traumatic injury than the control. Although the blood pressure of the traumatized normal animal is higher than that shown by the deafferent dogs in which an equivalent reduction in blood volume has been produced by muscle trauma, the chances of survival of the former group are not any better; indeed, these chances are definitely worse. *It is the quantity of blood flow to the important tissues rather than the blood pressure alone which is the important factor in determining the fate of animals in shock. Our data again indicate that afferent impulses reflexly excite the sympathetic nervous system and thus may exert a detrimental effect on the traumatized animals by a further reduction of the tissue blood flow, this being the result of increased peripheral vasoconstriction.*

Fluid shifts as effected by changes in capillary hydrostatic pressure and reflected in altered hematocrit values and plasma protein concentrations are likewise in agreement with the contention that afferent impulses stimulate the sympathetic nervous system. It has been shown that sciatic stimulation in the sublethally hemorrhaged dog decreases the inflow of fluid into the blood stream and increases splenic contraction (see Table II).²⁸ On the other hand, in traumatized animals in which afferent impulses from the injured area have been excluded, there appears to be a more appreciable fluid shift into the plasma compartment and a lesser contraction of the spleen.^{*42}

The sympathetic nervous system is stimulated by the buffer nerve mechanism in shock produced either by hemorrhage or by muscle trauma.⁴⁴ It has been shown by Freeman, *et al.*⁴⁵ that a totally sympathectomized animal, though able to tolerate a low pressure for a long time, is not able to withstand an equivalent volume of blood loss as a normal animal. Thus, it is evident that the sympathetic vasoconstrictor effect is a compensatory mechanism, adapting the capacity of the system to the available volume of blood within it. Since additional vasoconstriction is associated with afferent stimulation and since

TRAUMA DOG D22# WEIGHT 10.3 KGM WITH DORSAL ROOTS CUT

	BEFORE	AFTER
BLOOD VOLUME, ml	93	63
HEMATOCRIT, %	44	49
SERUM PROTEIN, gm%	6.2	5.6

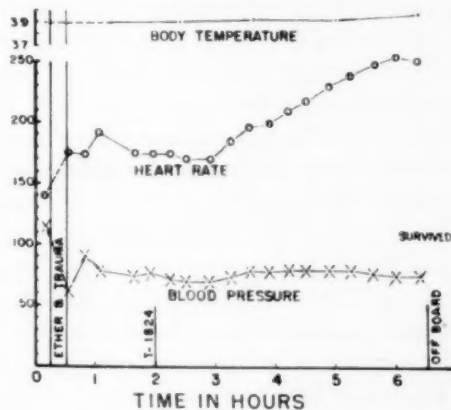


FIG. 4.—The clinical manifestations of a chronically deafferented dog (D 22) which has been subjected to muscle trauma. The blood volume reduction is comparable with that in dog H 13 and dog T 31 (Fig. 1). Note the slowly increasing tachycardia and low blood pressure level in this dog and compare it with that in the hemorrhaged dog H 13. Like dog H 13, D 22 survived the injury (from Wang⁴²).

* While the increased hematocrit in the trauma series and in the hemorrhage plus stimulation series (compared with that in the deafferent series and the simple hemorrhage series respectively) may be a liability, it is not of sufficient magnitude to alter the viscosity to such an extent as to be a factor responsible for the increased mortality rate in the former two series.⁴³

this more intense constriction develops much earlier in the clinical course than that associated with simple hemorrhage, a reduced volume flow over a relatively long period of time is the result. And although the early vasoconstriction of traumatic shock results initially in a higher blood pressure, its insidious action in contributing to prolonged tissue anoxia cannot be ignored.^{46, 47} While certain aspects of this concept are not new,⁴⁸ emphasis should perhaps be placed upon the early development of an intense constriction associated with trauma and its maintenance throughout the clinical course. Likewise, one might point out that adequate restoration of blood volume, undertaken sufficiently early before irreparable anoxic damage has occurred, should lead to recovery. Thus, although afferent impulses might appear to be of secondary importance to the reduction of blood volume, they nevertheless contribute deleteriously to the course of many traumatized animals and, indeed, in sublethal hemorrhages may well be the final precipitating cause of fatal shock.

It would be unwise to assume that a factor which is of predominant importance in contributing to the fatal course in one type of traumatic shock is necessarily of equal importance in shock produced by other traumatic means. For instance, in shock caused by tourniquet or crush, the increased apparent viscosity factor due to increased hematocrit values must also play a very important role in contributing to failure of blood flow.^{43, 49, 50} In burn shock, there is, in addition, a toxic factor.⁵¹ Human traumatic shock usually involves some external hemorrhage and the complication of bone fractures. On the other hand, hemorrhagic shock always involves some degree of trauma or pathology leading to the loss of blood. Furthermore, in many reported cases of shock in the human, the necessity of early therapy complicates the analysis of the relative importance of the contributing factors as well as the mortality rate. Richards and his colleagues^{52, 53} have, however, presented a series of well documented reports, comparing the pathologic physiology of various types of shock in man, in which measurements were carried out previous to any therapeutic intervention. In a Harvey Lecture,⁵³ Richards reported that arterial blood pressure tended to be less depressed in hemorrhage, and calculated peripheral resistance therefore higher (as compared with skeletal trauma). This is in contradiction to what we have observed in the canine experiments.^{14, 15} This difference could be conveniently ascribed to differences in the neuro-circulatory mechanisms of man and dog. However, Richards and his collaborators⁵⁴ have more recently collected 26 cases of skeletal trauma in shock and nine cases of external hemorrhage in shock. The average total blood volume values per square meter of body surface area in both groups were about the same, 1910 cc. for the trauma cases and 1997 cc. for the hemorrhage cases. For the former group, the systolic blood pressure was 76 mm. Hg, diastolic 40 mm. Hg and cardiac index 2.16 liters per min. per square meter; for the latter group, systolic 76, diastolic 43 and cardiac index 2.42. Therefore, the hemorrhage group has a slightly lower calculated peripheral resistance than the trauma group, but the difference is not significant. Richards⁵⁴ gives the explanation for the relatively high blood pressure in the hemorrhage series

reported in his Harvey Lecture,⁵³ that the gastro-intestinal and external hemorrhage subgroups were lumped together, and several of the gastro-intestinal cases were slow or chronic bleeders and had in part compensated for their blood loss. Whatever the explanation, it is important to stress the fact that one rarely encounters a clear-cut hemorrhage or trauma case in a patient as one does in experimental animals.

In any case, the fact that patients are frequently in shock following traumatic injury with little loss of blood continues to be the experience of many surgeons. And it is certainly true that painful stimuli in the human also give rise to an immediate pressor response.⁵⁵ There is, therefore, some basis for inferring that similar differences exist between hemorrhagic and traumatic shock in man and that, if such differences exist, they are of similar etiologic origin to those described here in the dog.

It is well, perhaps, to point out that our data are not to be interpreted as illustrating or accounting for *all* of the differences in causative mechanisms between traumatic and hemorrhagic shock. Indeed, afferent impulses appear to explain only in part the differences in mortality rate as well as the dissimilarities in clinical manifestations of these two groups of animals. For example, although the mortality rate of hemorrhaged dogs is increased by the addition of sciatic nerve stimulation, it does not attain the level of the traumatized group. Similarly, the deafferent animals withstand muscle trauma with a greater blood volume reduction than normal dogs undergoing the same procedure, but again do not survive an equivalent volume reduction as do animals following uncomplicated hemorrhage. Such quantitative observations indicate that perhaps still another factor or factors contribute to death in traumatic shock. The other most prevalent one in the literature is a toxic factor, although experiments designed to prove the existence of this component are difficult to interpret and the evidence thus far accumulated is not conclusive.

Recently, Aub, *et al.*^{56, 57, 58, 59, 60} reported that ischemic muscle is an excellent medium for toxin production by *Clostridium welchii* which is normally found in dog muscle and skin. They further reported that the injection of fluid collected from such muscle, especially when artificially reinforced with exogenous clostridial toxin, resulted in a shock state similar to that of traumatized animals with the salient exception that the injected dogs showed an intense hemolysis. Aub, *et al.*⁵⁸ showed, however, that animals suffering from ischemic muscle damage with subsequent exudation and reabsorption of the exudates were able to withstand graded hemorrhage to an equal total loss of vascular fluid as normal dogs. They concluded, therefore, that the experiments failed to demonstrate the presence in the general circulation of any noxious substance liberated from the ischemic muscle which accentuates the appearance of shock.

We could not, of course, rule out the clostridial toxigenic factor in our experiments. However, the short survival time (average 4 hours, range 2 to 6 hours) and the presence of but slight hemolysis which was incident to the traumatic procedures are observations which are at variance with those found following the injection of exotoxin. In order to ascertain the importance of the

role of the clostridial toxic factor it would be necessary to study the protective action of polyvalent gas gangrene antitoxin, and to compare the mortality rate and clinical manifestations of treated traumatized animals with those of traumatized controls.

However, in evaluating the afferent nervous factor in our experiments, the fact that the deafferentation conferred upon these animals the ability to withstand muscle trauma with a greater loss of blood volume than normal traumatized dogs—in neither groups were possible bacterial contaminants excluded—indicates clearly the importance of a neurogenic component in experimental traumatic shock.

SUMMARIES AND CONCLUSIONS

1. Quantitative studies are presented which reveal a statistically significant difference in mortality rate between groups of hemorrhaged dogs on the one hand and traumatized dogs with equal blood volume reductions on the other. This indicates that loss of circulating volume alone is not adequate to explain the high mortality rate in experimental traumatic shock.

2. Certain other differences in the clinical manifestations were observed in the two groups of animals, indicating an earlier and more intense activity of the sympathetic nervous system in the traumatized group.

3. Animals subjected to sublethal hemorrhage followed by prolonged stimulation of the central ends of the cut sciatic nerves showed a mortality rate significantly higher than that of animals with an equal blood volume reduction from hemorrhage alone. The clinical signs exhibited by this group were closely similar to those shown in the trauma series.

4. In another series of animals in which trauma was prolonged after previous deafferentation of the hind limbs, the mortality rate at a given level of blood volume reduction was significantly reduced from that shown by normal traumatized dogs. The clinical signs exhibited by this group were closely similar to those shown by the hemorrhaged animals.

5. These studies indicate that an afferent nervous factor, second in importance to blood loss, is an essential causative mechanism in experimental traumatic shock.

6. From numerous differences in clinical manifestations between the hemorrhage and deafferent-trauma groups on the one hand and the trauma and sublethal hemorrhage plus sciatic stimulation groups on the other, it is postulated that afferent impulses arising in the area of injury reflexly produce an intense and prolonged activity of the sympathetic nervous system. While such sympathetic activity operates to maintain a higher blood pressure level and may indeed be considered a compensatory mechanism early in the shock syndrome, the extreme and lasting vasoconstriction may become finally detrimental to the animal through further reduction in tissue blood flow and its sequelae—tissue hypoxia and acidosis.

7. The relation of these experimental observations to the traumatic shock syndrome in man is reviewed.

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A DISCUSSION OF TENDON REPAIR

WITH CLINICAL AND EXPERIMENTAL DATA ON THE
USE OF GELATIN SPONGE*

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THE REPAIR OF TENDONS in the hand calls for a variety of surgical technics. The problem is quite different in the finger, in the palm, in the wrist and on the back of the hand. The poorest results are in the ensheathed portion of flexor tendons. These cases frequently end up with an amputation. Although an amputation of a finger with a damaged flexor tendon is often desirable in a manual laborer, it may mean the loss of ability to earn his living in a skilled workman and where there are multiple injuries, repair may be imperative.

The causes of failure in the repair of ensheathed tendons are inherent in the structure of the tendon itself. This highly specialized physiologic unit is essentially an untwisted cable of fibro collagenous material covered by a single layer of easily damaged flattened cells. It glides in a tube-like sheath of similar material which is alternately thinned out over the joints and thickened along the shafts of the bones. The blood supply to an ensheathed tendon as commonly described consists of vessels carried in the vinculae (which constitutes a meso tendon) and of a central vessel in the tendon. After examining microscopic cross sections of at least 20 damaged tendons, I have been unable to identify the central vessel in any of them and I am convinced that this vessel is missing or becomes thrombosed following an injury.

When a tendon is severed the ends retract and considerable additional trauma is inflicted before the ends are recovered and reunited by suture. Experimental evidence¹ has shown that a tendon in healing first becomes a part of the surrounding tissues and later as the result of stimulus to function develops a new gliding mechanism. Unfortunately, it often happens that the traumatized tendon swells and becomes ischemically strangled in the tightly fitting sheath, and finally heals with dense adhesions to the sheath. Many of these adhesions were formerly blamed on infection but elimination of infection has not brought success in repairs although its presence certainly is disastrous.

Some adhesions may be present in certain locations without entirely limiting function. For example, a repaired profundus tendon may be partially adherent in the middle segment of the finger and still activate the end phalanx satisfactorily. This is because the tendon needs only a short gliding action here to mobilize its phalanx. The poorest results in tendon repair are obtained when the junction is made over the metacarpal heads and at the base of the fingers. Any limitation of glide here interferes seriously with finger action. There is no angle of pull to free the tendon here and the tendon distal to the repair also becomes adherent, thus a stiff finger is the usual result.

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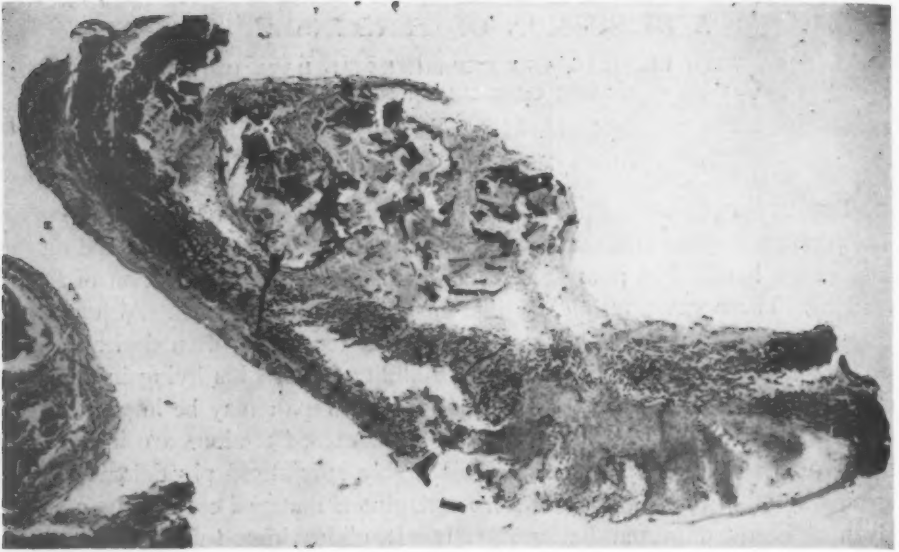


FIG. 1.—Low power photomicrograph of biopsy at two weeks. Black material gelatin sponge.

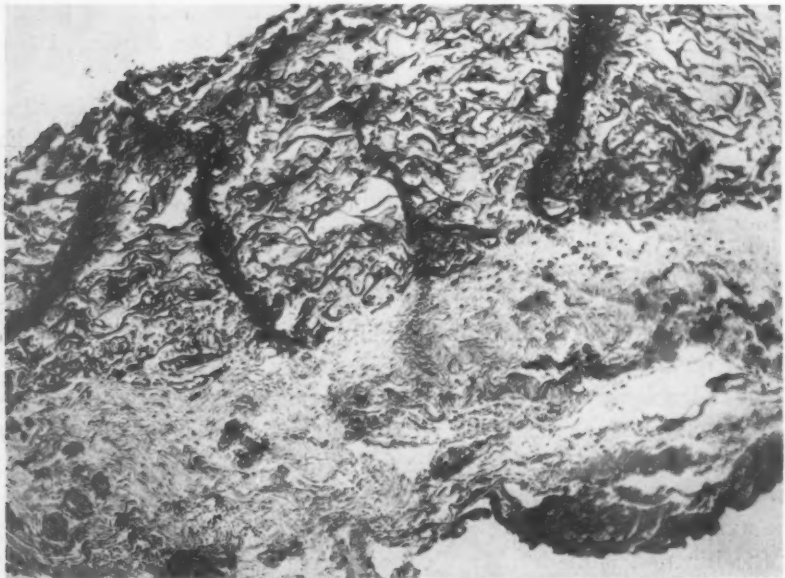


FIG. 2.—High power photomicrograph of biopsy at two weeks.

TENDON REPAIR

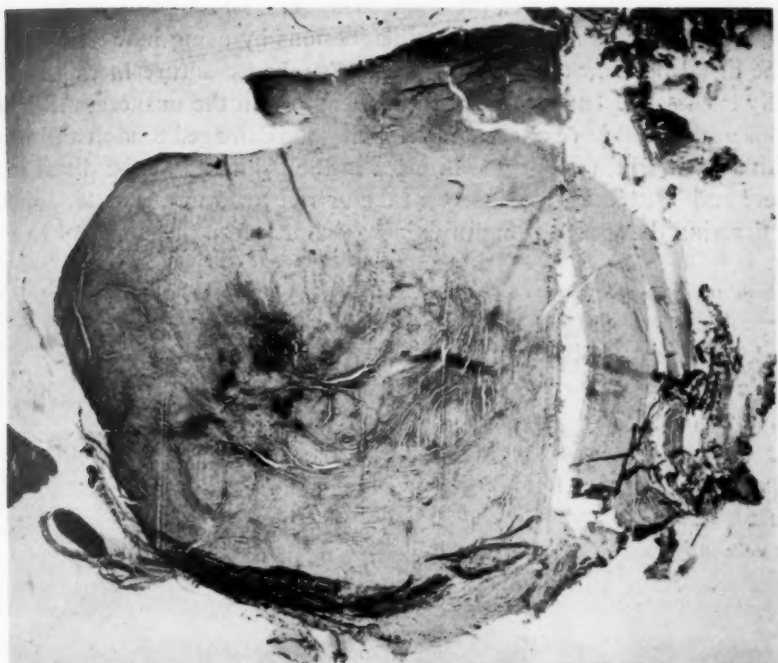


FIG. 3.—Biopsy at one month showing no reaction about tendon. Sponge absorbed.

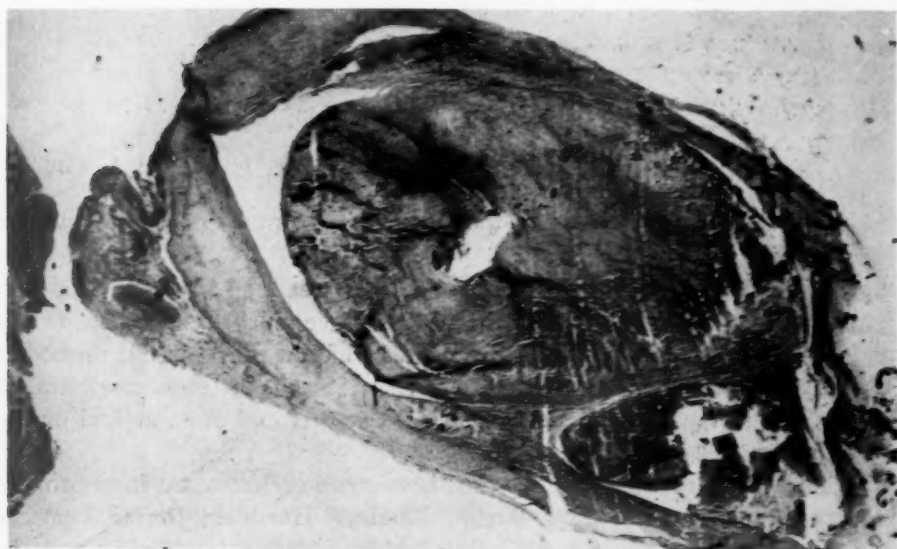


FIG. 4.—End-to-end suture showing extensive fibrosis.

The principles underlying the repair of tendons have, as their basis, the attempt to avoid adhesions in the dangerous areas. In the palm, tendons may be sutured and the repair protected from adhesions by using lumbricales muscles. At the distal phalanx no motion is necessary, hence suture in this location is usually successful. In an attempt to avoid suture in the unsuccessful locations, various authorities have advocated removing the damaged tendon and replacing it with a graft which is sutured in place in the palm and at the distal phalanx. Mayer² and Thatcher³ first insert a tube or rod to form a new tendon sheath, later drawing the graft through this new channel. Bunnell⁴ prefers to graft in

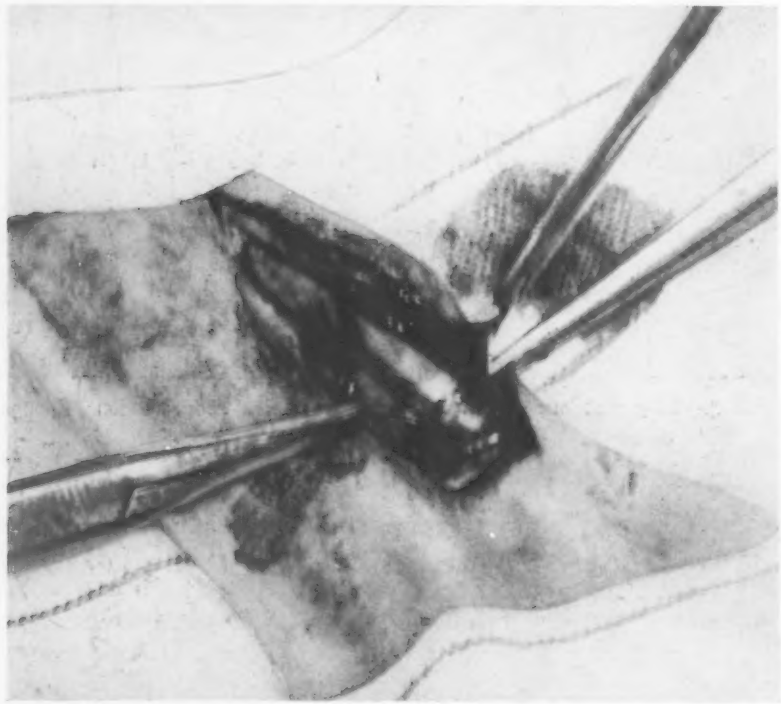


FIG. 5.—Dog at two weeks showing sheath slit—no reaction about tendon.

a complete unit of tendon and tendon sheath such as the palmaris longus with its paratenon. Unquestionably these methods have much to recommend them and there are many situations where they provide the only possible method of repair. The principal objection to the use of grafts in ensheathed tendon repairs is that the graft is poorly nourished at first and must depend on the surrounding tissues for its blood supply.

The trend in recent years has thus been more or less away from primary repairs of ensheathed tendons. Iselin,⁵ Dudley,⁶ Handfield Jones,⁷ Thatcher and other surgeons experienced in this field have definitely given up primary suture. On the other hand Bunnell and Koch⁸ and Mason⁹ still prefer primary repair but set a time limit on the interval between laceration and repair. Cer-

TENDON REPAIR

tainly infection in any case is disastrous. The author's experience is that an empty tendon sheath may get infected with results as damaging as a filled one. The trauma of the operative repair simply complicates this infection and makes it worse. Rarely, a primary repair is successful enabling function to be restored earlier, more completely and much more simply.

When a primary repair is undertaken, some additional procedure is usually done to prevent adhesions from completely limiting tendon motion. Bunnell recommends slitting the tendon sheath in the segment involved. Koch and Mason excise a window in the sheath over the repair site. In either primary or



FIG. 6.—Dog at one month. Tendon free.

secondary repairs, fat or fascia have been wrapped about the tendon junction and a variety of foreign substance such as amniotic membrane, cellophane, tantalum, foil, etc., have been tried to prevent the healing tendon from becoming adherent. Under any circumstances a good tendon is essential if a successful repair is to be effected. A scarred tendon lying in a scar tissue bed will inevitably become adherent. The success or failure of any foreign material introduced would certainly seem to depend on the ability of the body to convert this material into tendon sheath-like tissue.

One simple method of tendon repair which avoids the difficulties of either graft or end-to-end suture is the so-called tendon advance operation described by Cutler,¹⁰ and referred to by Littler¹¹ but otherwise rarely mentioned in the literature. In this procedure the proximal tendon stump is brought down and

sutured to the distal stump as close to its insertion as possible, excising the distal tendon between the point of laceration and the distal digital crease. This maneuver places the tendon juncture at the distal crease where no motion is needed and avoids the laceration area where adhesions are sure to form.

I have used this method successfully on about 15 cases since 1944. Practically, this procedure is most useful when the profundus tendon is severed in the middle segment of the finger. Theoretically, it might also be used to give

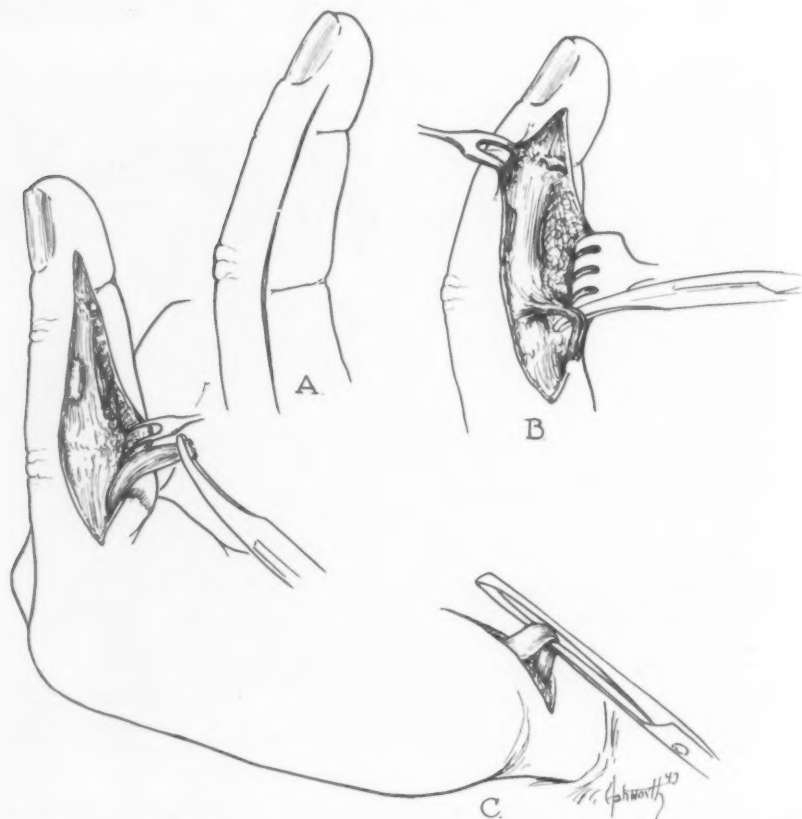


FIG. 7.—Technic of tendon advance operation. A. Midlateral incision. B. Dissection of scar tissue. C. Tendon freed.

motion to the middle joint when the profundus is severed within an inch of the middle crease, since the tendon can usually be advanced about an inch. In practice a graft is usually used in this area.

In doing secondary repairs, the following technic is used (See illustration): The finger is opened through a mid lateral incision and the tendon sheath detached from the bony phalanx along one side. All scar tissue is excised and the tendon ends dissected out so that good tissue is available for repair. If the proximal tendon stump can then be drawn down to the distal digital crease with the wrist and finger flexed, the advancement operation can be carried out with

TENDON REPAIR

success. A considerable tension is present in some of these cases the tendon is secured by wire passed through a drill hole in the phalanx. A heavier wire than is usually described is used for this anchoring suture and it is inserted in such a way that it can be removed from the distal end. This allows the wire to be left in place a month if necessary without forming adhesions or causing infection. Before closing the incision, the exposed tendon is surrounded with strips of gelatin sponge.*

The wound is closed with external sutures only, leaving the remaining tendon sheath slit throughout its length. The hand is dressed in a plaster

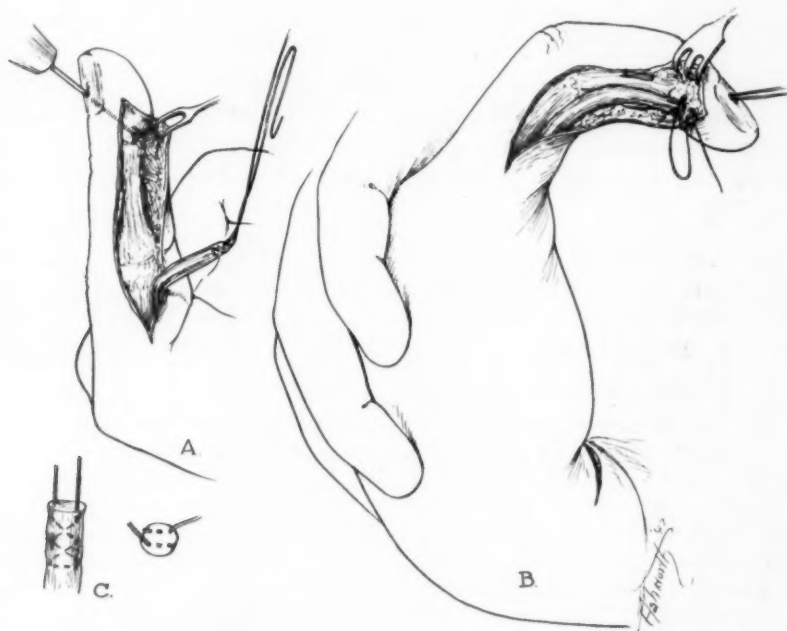


FIG. 8.—Technic of tendon advance operation. A. Suture inserted. Phalanx drilled. B. Tendon advanced to new insertion. C. Method of inserting suture.

mould with the wrist flexed. Active exercises are started after the skin wound heals, the patient being first instructed to attempt to gently, actively, straighten the finger.

The gelatin sponge was first used to control hemorrhage from the bare area left after excision of the scar. Later, it was found that these fingers had a better range of motion than was expected. To substantiate this clinical finding, the following animal experiments were carried out. Six healthy dogs were used and the achilles tendon was exposed, wrapped with gelatin sponge and biopsied at two week intervals. The tendon was also sectioned, sutured and the juncture wrapped. It is fully realized that the achilles tendon is not an ensheathed tendon but it is the tendon which has been customarily used in

* Gelatin sponge used was Upjohn Co. Gelfoam No. 12.

animal experiments. From the accompanying photographs and photomicrographs, it can be seen that the gelatin sponge gross dissection does tend to show a shiny surface upon which the tendon glides. Microscopically, there is very little reaction and there is found between it and the moving tendon a thin space lined by a single layer of flattened cells, very much like tendon lining. When placed around a sutured tendon, however, dense adhesions are found.

Clinically, it has been found that there are certain definite indications and contraindications to the use of this substance in tendon surgery. It does definitely cause an increase in serum collections and autolysis of inadequately nourished tissues. For this reason it should not be used about grafts or about tendon junctures as it prevents healing in these cases. On the other hand it has been found useful in preventing sound tendons from becoming encased in adhesions in the tendon advance procedures.

The following case reports indicate some of the cases in which gelatin sponge has been used and the results obtained. There is also included a comparison series of the standard type case treated with and without gelatin sponge.

CASE REPORTS

Case 1.—WA. Age 26. Caught thumb in rip saw 10/2/47 lacerating palmer surface, severing digital nerve and tendon. Unsuccessful primary tendon suture done elsewhere. Unable to move distal joint. Repair 3/17/48 using author's technic with gelatin sponge. Healed with serum collection. Examination 6/23/47 almost full function present. (See Fig. 10.)

Case 2.—JC. Age 59. Bottling machine broke bottle, lacerating ring and little fingers 2/11/47, severing digital nerves and profundus tendon of little finger. Repaired 4/19/47. Author's technic with gelatin sponge wrapping. Primary healing. Examination 8/6/47, able to touch palm actively and forceably. Lacks a few degrees of full extension. (Little finger usually least successful in tendon repairs).

Case 3.—HM. Age 26. Caught index finger on cylinder block 5/23/47. Lacerated profundus tendon and digital nerve. Repair 7/14/47. Author's technic, gelatin sponge used. Healed by first intention. Examination 10/7/47 showed 45 degrees of independent active motion of distal joint. Able to touch palm but 30 degrees lack of extension due to previous scarring.

Case 4.—CS. Age 41. Saw laceration of right middle finger severing profundus tendon near insertion 8/16/47. Primary repair done elsewhere, unsuccessful. Operation 1/5/48 found profundus tendon retracted into palm and degenerated. Sublimis tendon adherent and inflamed. Profundus excised, sublimis wrapped with gelatin sponge after freeing, distal joint fixed in 30 degree flexion. Patient regained good painless range of motion, touches palm.

Comment. In some cases recovery of profundus is impossible. To use a graft would necessitate sacrifice of good sublimis. This is not advisable.

Case 5.—EG. Age 30. Index finger cut in middle segment on tin strip 7/3/47. Digital nerve and profundus tendon severed. Immediate repair. Author's technic without gelatin sponge. Examination 11/14/47. Has full extension, almost full flexion. (See Fig. 11.)

Case 6.—BD. Age 41. Finger cut by metal on drill press 6/20/46, both tendons severed in proximal segment. Immediate suture done elsewhere through anterior incision. Absolutely unsuccessful. Repair 10/16/46, author's technic but without gelatin sponge. Primary healing. Examination 2/24/47 active motion 90 degrees proximal joint, 80 degrees middle joint, 30 degrees distal joint. Finger tip almost touches palm.

Comment.—Enough of profundus left to carry out repair.

TENDON REPAIR

Case 7.—CR. Age 32. Cut index finger on knife 6/46, both tendons cut in proximal segment. Primary suture done elsewhere through anterior incision. Absolutely unsuccessful. Repair 1/27/47, author's technic without gelatin sponge. Healed per primum. Examination 4/29/48, tip almost touches palm.

Case 8.—PS. Age 43. Plow shear fell onto hand 4/4/46. Suffered laceration middle and ring fingers across middle creases. Profundus tendons cut both fingers. Repair 6/25/46. Proximal tendon ends were resutured to distal stumps using pull out wires tied over buttons on ends of fingers. Ring finger failed to function. Reason, distal stump left too long. Resutured 8/2/46 using author's technic. Examination 11/6/46, active full motion of proximal joints. All middle joints 90 degrees. Distal joints 35 degrees. Touches palm strongly.

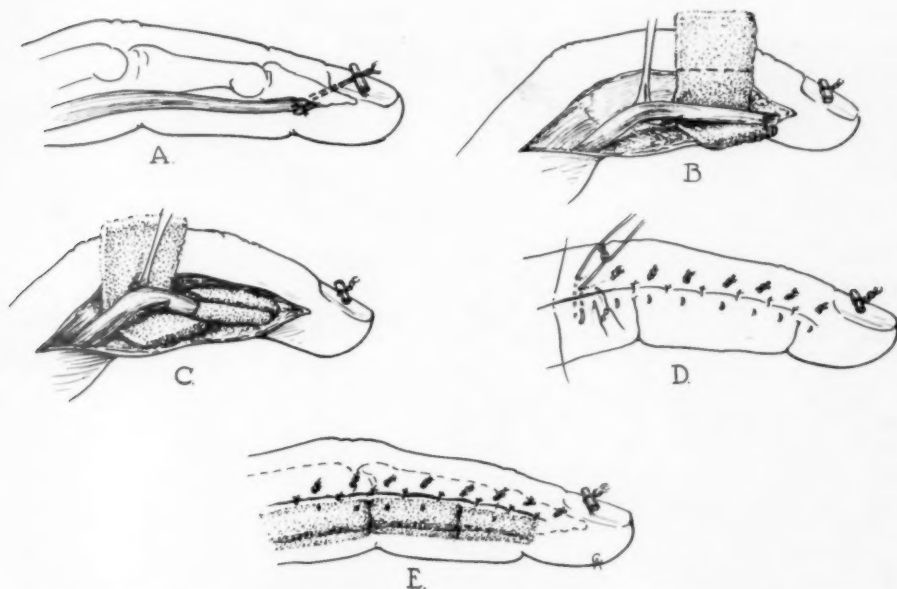


FIG. 9.—Technic of tendon advance operation. A. Tendon repair complete. B and C. Gelatin sponge wrapping applied. D and E. Wound closed.

Comment.—Fingertips scarred by buttons in this case. Later cases drilling phalanx avoided this difficulty.

TENDON GRAFTS

Case 9.—LP. Age 20. Saw injury 2/14/47 sustaining amputations of little and ring fingers and part of thumb with loss of soft tissues over proximal segment of middle finger. Soft tissue first replaced with abdominal flap. Tendon graft inserted 6/21/47 surrounded with gelatin sponge. Wound failed to heal. Tendon removed 7/8/47, showed marked softening and inflammatory infiltrate. Second tendon graft done without gelatin sponge 11/4/47 and was successful.

Case 10.—LS. Age 37. Saw cut dorsum of hand 3/12/47, severed extensor pollicus longus. Sutured elsewhere, function did not return. Secondary repair was done 5/27/47. The extensor of the fourth toe was removed and used as a graft. Tendon junctures were effected by interweaving tendon ends and these areas were wrapped with gelatin sponge. Healing delayed. Examination 7/1/47 showed some return of function but full extension was not present, evidently due to tendon junctures separating.

Comment.—Out of a series of tendon grafts done in the past few years, these cases are the poorest results of their respective types. Gelatin sponge should not be used around tendon grafts.

END-TO-END SUTURE

Case 11.—CB. Age 30. Glass cut volar surface of index finger 7/3/47. Both tendons cut at proximal crease. Immediate repair using Bunnell suture at a distance technic. Tendon juncture wrapped with gelatin sponge. Healed kindly. Examination 5 months later showed poor function (due to extensive adhesions at operative site). Case reoperated 4/10/48, tendon freed. Good result.

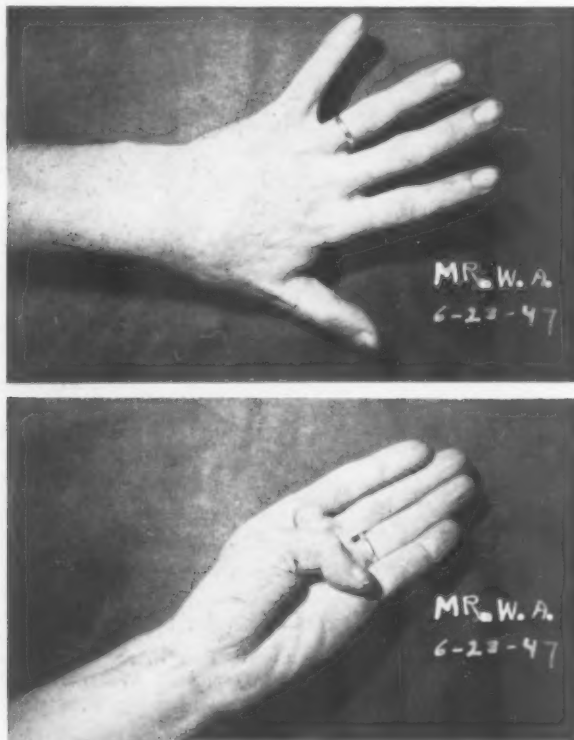


FIG. 10.—Illustration, Case 1. Flexor tendon repair in thumb showing full return of function.

Comment.—Animal experiment shows excessive fibrosis about tendon juncture. See plate. Gelatin sponge should not be used here.

Case 12.—NC. Age 25. Run over by motor boat 8/4/47. Multiple lacerations of hand and forearm with fractures of carpals and metacarpals, and division in carpal canal of flexor pollicis longus and both flexors of index finger, also double lacerations of flexor carpi radialis in forearm. Repair 8/25/47: Through boot hook incision, the transverse carpal ligament being detached on its ulnar side, the wrist and forearm were widely opened. Tendons in canal repaired end to end using Bunnell stitch with stainless steel wire. Tendon juncture wrapped with gelatin sponge to protect median nerve which had been superficially lacerated. Tendon graft used to fill gap in forearm in flexor carpi radialis. No gelatin sponge. Wound healing satisfactory. Examination 5/4/48, full function but thumb and index finger working together.

TENDON REPAIR

Comment—Apparently gelatin sponge tolerated well in carpal canal. I believe, however, that a sleeve of areolar tissue would have been better here.

Case 13.—DG. Age 20. Window glass cut dorsum of wrist 6/14/47. Multiple laceration, all tendons being severed in center of posterior annular ligament. Repaired 12 hours later. Finger extensors repaired by interweaving their ends, extensor carpi ulnaris end to end using a pull out wire fastened over a button. Gelatin sponge used about all tendon junctures. Healed by first intention. Examined 6/3/48, full function but extensive fibrosis about tendons.

TENDONS CUT IN WRIST

Case 14.—RH. Age 16. Fell into water catching right wrist on bolt of submerged log 4/12/47. Multiple lacerations. Flexor carpi radialis severed near insertion. Immediate repair using pull out wire—fastened to button in palm. Tendon juncture wrapped with gelatin sponge. Healed kindly. Full function in one month.

Case 15.—VO. Age 22. Fell, cutting palm and snuff box area 5/4/47. Abductor pollicis longus sutured with pull out wire fastened to button on dorsum of thumb. Tendon juncture wrapped with gelatin sponge. Wound healed by first intention. Examined one month later. Full function.

Case 16.—JO. Age 56. Stuck hand through glass door 7/30/47. Multiple lacerations severing flexor carpi radialis, extensor pollicis brevis, abductor pollicis longus also ulnar nerve and flexor carpi ulnaris. Tendons repaired with pull out wires tied over buttons in palm, junctures wrapped with gelatin sponge. Wound healed per primam. Examination 8/27/47 showed good return of function. Photo 4/30/48, almost full function even of ulnar nerve. Small finger muscles not working.

Comment. — Gelatin sponge apparently well tolerated on back of hand and wrist but not necessary.

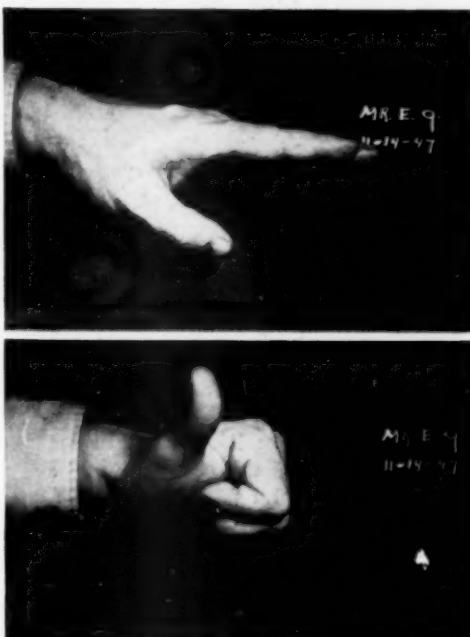


FIG. 11.—Illustration, Case 5. Index finger tendon severed in middle segment. Showing amount of function four months later.

DE QUERVAIN'S DISEASE

Case 17.—MH. Age 48. Suffered fractured navicular 7/28/48. Painful swelling along tendon sheath began two months after removal of cast. Operation 1/8/47. Typical stenosing tenovaginitis of sheath, of extensor brevis and abductor longus of thumb. Sheath split. Patient was well for two months, then symptoms recurred. Reoperated 4/4/47. Found tendons again markedly inflamed. Excised sheath and granulating tissue, wrapped tendons with gelatin sponge. Healed uneventfully. Reported cured 12/20/47.

Comment.—Apparently gelatin sponge well tolerated in this case.

DISCUSSION

The variety of cases presented above include not only ensheathed tendons but also tendons surrounded with paratenon, it being the author's purpose to

try this material in every conceivable type of tendon repair. In analyzing the results obtained, it can be seen that in most locations there is no special advantage in using the gelatin sponge.

SUMMARY

Clinical and experimental data on the use of gelatin sponge is presented with the following conclusions:

1. The sponge may be placed around a sound tendon without danger and apparently allows earlier free tendon motion here.
2. When used about a tendon juncture the sponge causes excessive fibrosis and prolonged fixation of the tendon.
3. Tendon grafts are apparently autolyzed when surrounded by gelatin sponge.

Experimental work was carried out at the University of Oregon Medical School laboratory.

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A TECHNIC OF EXPOSURE FOR DIVERTICULA OF THE THIRD AND FOURTH PARTS OF THE DUODENUM*

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The technics of exposure utilized in the operative treatment of diverticula of the third and fourth parts of the duodenum have apparently changed little since the publication of the classic case reports of Forssell and Key (1915), Basch (1917) and Maclean (1927). Access to the duodenum has ordinarily been sought through the transverse mesocolon or through the gastro-colic omentum and the lesser omental sac. Diverticula occurring in anterior locations have then generally been dealt with by simple dissection, but procedures which have led to duodenal mobilization or elevation of the pancreas have almost invariably been used in the search for diverticula not at once exposed to view.

The mobilization of the duodenum in the latter instances has been achieved by recourse to a method commonly attributed to Kocher. Here the duodenal segments are reflected medially and thus restored to the position in which they lie before rotation during embryonic life. Additional technics of mobilization which have also been suggested are not known to have been used in the treatment of these lesions. A medial approach had been proposed by Clairmont and Schinz (1920), but in the review by Morton (1940) this procedure was considered difficult and ill-advised. A method used by Vautrin and Fourche (1923) for other lesions in the region of the proximal duodenum was thought suitable for diverticula of the distal segments by Kellogg and Kellogg (1931). A portion of the transverse colon was turned down in this procedure, and the duodenum was reflected with the pancreas medially. Subsequent reference to these methods has been limited because the surgical treatment of diverticula has not often been advised.

We wish to call attention at this time to a technic of duodenal mobilization which we have not found emphasized in any previous report.

TECHNIC

The duodenum is exposed by turning the transverse colon, mesocolon and great omentum upwards. An incision is begun in the posterior layer of the parietal peritoneum, just below and parallel to the inferior duodenal edge, and from this point it is extended, medially and laterally, until it underlies the third and fourth parts of the duodenum. The superior mesenteric vessels are retracted towards the patient's right, and by means of sharp dissection which

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FIG. 1.—Roentgenographic appearance of the diverticulum 6 weeks prior to operation.



FIG. 2



FIG. 3

FIGS. 2 and 3.—Photographs of a dissection of a cadaver to illustrate the mobilization of the third and fourth parts of the duodenum. Fig. 2 shows the exposed duodenal segments *in situ*, and Fig. 3 the segments after their dissection from the duodenal bed and after their rotation towards the subject's right.

is advanced proximally the outlined duodenal segments are separated from their bed. Their reflection also towards the right, which sometimes requires division of the ligament of Treitz, then brings their posterior surfaces into satisfactory view and permits easy access to the diverticula in this region.

This technic has been of value in a recent operation where massive fat deposits greatly interfered with the exposure of the pancreas and duodenum. Little bleeding was encountered, and the ease of the procedure was thought worthy of comment. The diverticulum (Fig. 1) originated from the mid posterior surface of the third part of the duodenum and lay wedged between the pancreas and the duodenal wall. Bulbous in outline, it was about 2 inches long and about 3 inches wide, with a neck $1\frac{1}{2}$ inches across. Dissection of the diverticulum from its pancreatic bed was accomplished easily. Amputation at the base was performed between two clamps, and closure of the defect in the duodenal wall was achieved by transverse suture and infolding of the stump. An adequate exposure was afforded for each stage of this procedure.

The effectiveness of this approach has also been demonstrated upon the cadaver (Figs. 2 and 3). With its application we believe that diverticula of the third and fourth parts of the duodenum may be identified without recourse to such auxiliary measures as the air injection technics suggested by Walzel (1935) and by Mahorner and Kisner (1947). We are also of the opinion that extensive elevation of the pancreas will not frequently be needed.

SUMMARY

An account is given of a technic of duodenal mobilization which has been found of value in the exposure of diverticula of the third and fourth parts of the duodenum.

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THE SURGICAL TREATMENT OF HERNIA₂ IN THE AGED

A STUDY OF EIGHTY-TWO CONSECUTIVE PATIENTS
OVER SIXTY YEARS OF AGE*

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THIS PAPER IS PRESENTED not merely as a statistical study but as a plea for the surgical treatment of hernia in old people. Many elderly patients complain for years of pain in the area of the abdomen affected by the hernia, or struggle with a truss prescribed by some well-intentioned physician, until incarceration, strangulation or intercurrent disease settles the issue. It has been assumed too often that a sedentary life or a degenerative disease precludes the necessity for herniorrhaphy. Yet the persistent symptoms of hernia themselves contribute largely to a state of invalidism. The teaching expressed in standard text-books of Surgery is exemplified in the "Textbook of General Surgery," by W. H. Cole and R. Elman,¹ who state in their chapter on Inguinal Hernia—"In elderly people the question of operability presents itself. If the patient is no longer required to work, and the presence of a hernia produces only moderate symptoms, there may be no advantage in performing an operative repair."

Dulin,⁷ in his series of 263 cases of elective hernioplasty in the aged, had ten deaths, or a mortality of 3.8 per cent. He had an infection rate of 8 per cent in cases done under local anesthesia. He, therefore, concluded that the repair of inguinal hernia in old people was dangerous and unsatisfactory.

However, there are other authors who believe that old people can safely receive the benefits of surgical treatment. In 1940 Quigley² analyzed 100 consecutive cases of inguinal herniorrhaphy in patients over 65 years of age. One of his patients died of pulmonary embolism 23 days after operation, so that his operative mortality was 1 per cent, certainly not a prohibitive figure. Both Brooks³ and Clagett⁴ feel that it is no longer logical to accept old age as an excuse for withholding operative treatment for dangerous and disabling diseases. With the gradual change in our population and the increase in the proportionate number of elderly patients³ the treatment of this group of people will demand more and more of the surgeon's attention. Both Bailey⁵ and Morton⁶ believe there is little evidence for the truth of the popular opinion that advanced age is a strong contraindication for operative treatment.

GENERAL CONSIDERATIONS

Between April, 1939, and April, 1946, 82 patients over 60 years of age were admitted to the second surgical division, for the treatment of various types of hernia. Practically all came from the City Home for the Aged and from the medical wards. Twenty of these were emergency cases. There were 70 males

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SURGICAL TREATMENT OF HERNIA

and 12 females. Ninety-five operations were performed on these 82 patients; 78 for inguinal hernia, 10 for femoral hernia, three for umbilical hernia and four for ventral hernia. Of the group of 20 emergency cases (incarceration and strangulation), nine were inguinal hernia, seven femoral, two ventral and two umbilical. In the group of elective cases there were 12 operations for direct, 52 for indirect, six for sliding and eight for recurrent inguinal hernias.

Thirty-six patients were between 60 and 70 years of age, 35 were between 70 and 80 years, 10 were between 80 and 90 years, and one woman with an incarcerated femoral hernia was 102 years old.

Fifty-seven patients or 69 per cent of the total number had a complicating chronic or degenerative disease. Thirteen had generalized arteriosclerosis, 12 had hypertension, seven coronary artery disease, four diabetes; and the others are listed in Table II.

TABLE I.—*Operations for Hernia.*

1. Total number.....	95
2. Inguinal.....	78
(a) Indirect.....	52
(b) Direct.....	12
(c) Recurrent.....	8
(d) Sliding.....	6
3. Femoral.....	10
(a) Male.....	2
(b) Female.....	8
4. Umbilical.....	3
(a) Male.....	2
(b) Female.....	1
5. Ventral.....	4
(a) Male.....	1
(b) Female.....	3

SYMPTOMS

The predominant symptom among the 62 patients in the elective group was pain, usually localized in the region of the hernia. The pain was almost constant and was aggravated by walking and standing. Thirty-eight patients presented this complaint. Eight patients complained only of the mechanical inconvenience of a protruding mass. A history of incarceration was given by three. Another three patients complained of pain and protrusion, and ten had no discomfort from their hernias. In short, 52 out of 62 old people who came under our observation had persistent discomfort or pain.

Seventeen patients had had their trouble for more than 10 years, two between five and 10 years, and 18 less than five years, while in 25 cases the length of time was not given in the history. Incidentally, seven gave a history of having worn trusses, and all seven maintained that the trusses either failed to retain the mass or else caused increased pain.

TECHNICAL CONSIDERATIONS

The 95 operations in this series were performed by 10 visiting surgeons and 14 resident surgeons. Forty-one of the procedures were done under local block anesthesia with either 1 or 2 per cent novocaine. General anesthesia,

usually inhalation of cyclopropane, oxygen and ether, was used for 30. Spinal anesthesia was the method employed in 15 cases. A combination of local infiltration and general inhalation narcosis was used in three patients while six operations were performed under combined local infiltration with intravenously administered pentothal. The method of choice was local block anesthesia with 1 per cent novocaine. In instances of mass replacement of bowel from scrotum into peritoneal cavity additional inhalation or intravenous anesthesia was sometimes necessary.

TABLE II.—*Associated Disease.*

Disease	Number
1. Generalized arteriosclerosis.....	13
2. Coronary artery disease.....	7
3. Hypertension.....	12
4. Diabetes.....	4
5. Neurologic disease:	
(a) Parkinson's.....	2
(b) C. N. S. lues.....	2
(c) Tabes dorsalis.....	1
(d) Hemiplegia.....	1
(e) Glioblastoma multiforme.....	1
6. Pernicious anemia.....	2
7. Rheumatoid arthritis.....	3
8. Peptic ulcer.....	1
9. Hypertrophied prostate.....	4
10. Caisson disease of bone.....	1
11. Tuberculosis of chest wall.....	1
12. Cataract.....	1
13. Cirrhosis.....	1
Total.....	57

Standard methods of repair were used. In inguinal hernia the Halsted technic was used in 42 cases, the Bassini in 28, the Ferguson in one, and orchiectomy with repair in seven. In femoral hernia the femoral canal was closed by external suture in eight cases and in two instances an abdominal exploration was also necessary. Three umbilical hernias were repaired by transverse overlap and the four ventral hernias by vertical overlap.

Silk was used as the suture material in 65 cases and catgut in 30.

COMPLICATIONS OF OPERATION

Infection of the operative wound occurred in five cases, giving an infection rate of 5.2 per cent. Only one of these infections involved structures below the level of skin; the organisms cultured from the wound being *staphylococcus albus* and *bacillus coli*. This moderately severe infection took place in a case done under general inhalation anesthesia for strangulated inguinal hernia with resection of bowel. In the other four cases the infection was limited to the skin. Two of the latter were done under local anesthesia and the remaining two under spinal anesthesia. Response to the sulfonamides and penicillin was prompt.

Bronchopneumonia complicated the postoperative course in 13 cases. Treat-

ment with sulfadiazine and penicillin was usually effective. Pneumonia will again be discussed in a subsequent paragraph as a cause of death.

Two patients developed a posterior crural phlebitis which responded quickly to treatment without sequelae. There was no instance of pulmonary embolus.

One patient had a cerebral accident on the 16th postoperative day. Another had a complicating epididymitis following operation. One man with cirrhosis of the liver, transferred from the medical ward for the emergency treatment of an umbilical hernia, suffered a massive gastro-intestinal hemorrhage postoperatively. Finally, one 83-year-old female, operated upon for a huge strangulated umbilical hernia went into shock from which she did not recover.

MORTALITY

Of the 62 patients who were operated upon as elective cases, one died, giving us a mortality rate in elective surgery of 1.6 per cent. When operation became emergent, as happened in 20 patients, the figure rose sharply to eight deaths—a mortality of 40 per cent. In the entire series of 82 patients, there was a total of nine deaths, constituting a mortality of 10.9 per cent for elective and emergency cases. Following are brief outlines of the cases that died.

Case 1.—*Elective.* S. B., male, age 66, operated upon for large right sliding inguinal hernia involving cecum, on July 16, 1943. Twelve days later smaller left inguinal hernia repaired. On 14th postoperative day, while out of bed, he had a right hemiplegia and died on the 16th postoperative day. Necropsy—glioblastoma multiforme of brain, pulmonary edema, small right perinephric abscess.

Remaining eight cases were all emergent.

Case 2.—W. H., male, aged 74, in hospital for cirrhosis of liver and chronic myocarditis, was operated upon for strangulated umbilical hernia, and died on second postoperative day after vomiting a large amount of blood.

Case 3.—E. B., female, aged 83, was operated upon for a huge strangulated umbilical hernia containing most of colon, ileum and part of jejunum. She died five hours postoperative of shock.

Case 4.—E. B., female, aged 72, was operated upon for an incarcerated ventral hernia and died on the 4th postoperative day of pneumonia. Also had an old left hemiplegia, diabetes, auricular fibrillation.

Case 5.—T. L., male, aged 78, in hospital for arteriosclerotic heart disease underwent operation for strangulated left inguinal hernia and died six weeks later of pneumonia.

Case 6.—A. F., female, aged 60, operated upon for strangulated left femoral hernia and gangrene of small intestine, died on the second postoperative day in uremia.

Case 7.—G. McE., male, aged 75, in hospital for pernicious anemia, was operated upon for strangulated right inguinal hernia and died two months later of sacral decubitus and pneumonia.

Case 8.—V. B., female, aged 81, in hospital for diabetes and generalized arteriosclerosis was operated upon for incarcerated ventral hernia and died eight days later of cerebral accident and pneumonia.

Case 9.—G. C., female, aged 80, in hospital for hypertension and chronic cardiovascular disease, died 14 days after operation for strangulated right femoral hernia, of pneumonia and uremia.

These summaries are presented not only to give a description of the causes of death in our series but also to give an insight into the type of patient treated. Six of these people were already in hospital for treatment of a chronic disease

and developed their acute surgical condition while on the medical wards. In addition, since the Goldwater Memorial Hospital is an institution for the chronically ill, patients continue treatment on our wards longer than in the average general hospital. It will be noted that cases 1, 5, 7 and 9 died two weeks or longer following operation, when they were actually recovered from the immediate effects of surgery. They were still on our wards because of some chronic medical disease, and therefore were included in our surgical mortality figures.

COMMENT

The series of cases just described constituted a unique "poor-risk" group of patients. Most of them came from the New York City Home for the Aged on Welfare Island. They were people who, in general, had been subjected all their lives to the physical and psychic trauma of poverty. Others were transferred from the medical wards where they were being treated for chronic medical conditions.

Patients in the elective group were prepared for operation as for any major surgical procedure. Protein, vitamin and hemic deficiencies were corrected by diet and, when necessary, by parenteral therapy. Consultation with the medical service for the evaluation and correction of pulmonary and cardiac disease was of valuable aid. Thus, three of our patients required careful digitalization before operation. All three had uneventful postoperative courses. It was deemed inadvisable to operate upon patients who had kidney insufficiency as indicated by high nonprotein nitrogen content of the blood. Two men in the latter category underwent successful operation for hernia after preliminary surgery for hypertrophied prostates. Patients with active pulmonary disease were not subjected to surgery.

The anesthetic of choice is 1 per cent novocaine block infiltration, for inguinal, femoral and small umbilical hernia. When this is inadequate, supplementary inhalation of cyclopropane and oxygen can be used. In this series of cases, wound infection was not increased by the use of local anesthesia.

Silk is the favored suture material since its use, according to the principles of Halsted,⁸ produces less wound reaction than catgut. No particular technic of repair is recommended, since individual cases vary so much.

Of more importance than the type of repair is strict adherence to the fundamental surgical principles of gentleness in the treatment of tissues and avoidance of elaborate procedures. When the patient agrees, orchidectomy is justified if deemed absolutely necessary for the security of the repair. In bilateral inguinal hernia, we prefer that the operation be done in two stages at about a 12-day interval.

The patient is allowed out of bed on the day after operation. Here, again, the usual precautions in regards to early ambulation should be taken. Thus, a rapid pulse or high temperature indicates that the patient is to remain in bed.

Pneumonia was the most frequent complication. The 13 patients whose courses were complicated by pulmonary disease had the bronchopneumonic

type. The disease became evident at any time from the second postoperative day onward, and the earliest physical signs were found at the bases of the lungs. Of the nine patients who died, four had pneumonia as a cause of death.

Infection of the operative wound was not a serious complication in this series of cases. Only one severe infection, and four superficial ones occurred. The repair remained intact in all five cases.

The striking factor in our mortality figures was the greatly increased risk in emergency surgery for hernia. Thus, there was one death in 62 patients who were treated as elective cases and eight deaths in 20 emergency cases. It would seem to be logical medicine and good surgery to treat the elderly patient for hernia before he becomes a surgical emergency.

The question of recurrence of hernia will not be considered in this paper.

CONCLUSION

A series of 82 poor-risk patients over 60 years old, operated upon for hernia, has been presented. Sixty-nine per cent of these patients had a complicating chronic or degenerative disease. Fifty-two of the 62 patients in the elective group had persistent symptoms from hernia which contributed greatly to their invalidism. Where trusses were worn, they were inadequate. Operation had been deferred for years because of "old age" or a chronic medical condition.

In the group of 62 elective cases, one patient died of a cerebral accident and brain tumor 16 days after operation. Of 20 patients subjected to emergency surgery, 8 died. The contrast between the mortality figures in these two groups offers a graphic argument for the elective use of surgery in the treatment of hernia in the aged.

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SURGERY IN SITUS INVERSUS*

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TRANSPOSITION OF THE VISCERA is an unusual anomaly in which the positions of the abdominal and thoracic viscera are reversed, producing a relationship which has been well described as "the mirror image of normal." Although this condition is, in itself, not a serious hazard to normal health and longevity, its early recognition is of extreme importance in the treatment of many diseases, especially those requiring early surgical intervention. The purpose of this report is to present a brief review of the literature on this subject and to summarize those recorded cases in which surgery has been performed.

HISTORY

Although Aristotle¹¹⁷ first described this anomaly in animals, it was not recognized in the human until the 17th century when it was described in the writings of Fabricius¹³⁴ (1600), Servicus¹³⁴ (1615) and Riolan⁹² (1650). Beck⁷ states that one of the earliest recorded cases was that of Marie de Medici, Queen of France. Kuchenmeister¹¹⁷ in 1864 emphasized the importance of percussion and auscultation as an aid in diagnosis and Vehemeyer¹¹⁷ in 1897 was the first to discover a case by roentgen-ray examination. Since then cases have been recognized with increasing frequency, so that by 1938 Larson¹³⁴ estimated that over 475 had been reported.

INCIDENCE

The incidence has not as yet been established definitely, varying from .002 to .1 per cent as recorded in the literature (Table I). The close relationship between the total incidence found at autopsy (1-6, 164) and that found in mass chest surveys (1-6, 581) suggests that this anomaly will probably be encountered at least once in every six to eight thousand individuals. Although a busy surgeon, therefore, may expect to encounter this anomaly only once or twice in a lifetime, it is his responsibility in order to protect these individuals and to avoid embarrassing errors to familiarize himself with this anomaly and to consider it as a remote possibility in all cases of obscure abdominal pain.

ETIOLOGY

The etiology is also obscure. Apparently the embryo of a few millimeters is symmetrical so that in a medial sagittal plane the right and left sides are the mirror image of each other. According to Sherk,¹¹⁷ there is an altered relationship between the embryo and chorion, in which the right side of the embryo, rather than the left, is nearer the blood supply. As a result the cardiac tube assumes the position of a reverse "S" rather than a normal "S." Virchow¹¹⁷ emphasizes the significance of the reversed spiral twist in the umbilical

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SURGERY IN SITUS INVERSUS

cord. Von Baer¹³⁰ believes that the causative factor is an altered relationship between the embryo and the umbilical vesicle and Serre⁴ suggests that an abnormal development of the omphalomesenteric artery and liver may also play a role.

Because of the various degrees of transposition often seen in monsters, McMurrich⁸⁸ is of the opinion that these individuals are in reality the right twin of a duplicate monster, the left having been absorbed. Refutation of this theory lies in the fact that situs inversus is seldom seen in identical twins.

TABLE I.—Incidence.

Clinical Examinations		
Lewald ⁷⁸	1	135,000 Army Recruits
	3	63,000 clinical exams.
Hospital Admissions		
Massachusetts General Hospital ²	23	232,112
Willis ¹³¹	3	10,000
Mayo Clinic.....	10	347,000
Prescott and Zollinger ¹⁰¹	3	15,374
X-Ray Examinations		
Lewald ⁷⁸	29	40,000
(Many of these were referred after diagnosis had been made)		
Francisco and Ongpin ⁴¹	36	126,000
Sier and Clenet ¹¹³	30	280,000
Prescott and Zollinger ¹⁰¹	1	1,072
	5	50,000
Total.....	101	503,930
Minus.....	29	40,000
	72	463,930
Ratio.....	1	6,587
Autopsies		
Bell ⁹	3	30,000
Mayo Clinic (personal communication).....	3	10,000
Lewald ⁷⁸	1	50,000
Gunther ³	3	22,000
Adams and Churchill ³	1	8,000
Kehr ⁴⁰	2	10,000
Francisco ⁴¹	4	10,000
Rossler (Gall and Woolf) ⁴⁶	3	22,000
Total.....	20	117,000
Ratio.....	1	6,164

Some authors suggest that this is an acquired anomaly resulting from environmental influences on the fertilized ovum. Mall, Stockard and Newman² independently have emphasized the etiological importance of temperature, nutrition and growth rate. Speman⁹² has been able to produce various degrees of transposition in a few instances by surgically altering the medullary plate.

Other investigators believe this is an inherited anomaly arising in the germ plasma itself. Sumner and Heustis¹³⁴ conclude from studies on insects that situs inversus is the result of a recessive gene, probably in the third chromo-

some. This view is supported by Cockayne's¹⁸⁴ study of a large number of families and also by Feldman's³⁷ report of three cases in one family, the parents of which were first cousins. Reports by Feldman and Needle³⁸ and by Gall and Woolf⁴⁶ reveal that in the literature there are 25 instances of two or more cases in the same family, making a total of 54 recorded cases in which there is a known relationship. Although the authors conclude that such instances are exceedingly rare, the fact that less than one thousand cases in all have been recorded suggests that at least 1 in 20 is apt to have a relative with the same anomaly, offering rather strong evidence that these individuals are really mutants.

Adams and Churchill² suggest that there may be both the hereditary and the acquired types, the first giving rise to normal individuals and the latter to true monsters showing all gradations of transposition as well as other developmental anomalies.

TABLE II.—*Ages and Sex at Time of Surgery.*

Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	Not Given	Total
Number cases...	8	30	29	17	11	8	3	36	144
Sex									
Males.....									48
Females.....									65
No information.....									31
Total.....									144

CASE MATERIAL

Although this review attempts to be exhaustive, some cases have undoubtedly been overlooked. Also many of the records are brief so that all of the desired information is not present in each case. A review of the available data, however, summarizes fairly well past surgical experience with this anomaly and emphasizes the errors that have been made because the condition was not recognized.

The available literature reveals records of 144 patients with situs inversus who were submitted to 158 surgical operations. The transposition was complete involving all of the viscera in 125 cases; and partial, involving one or more but not all of the organs in 19. There were 48 males and 65 females. The ages at the time of surgery varied from 10 days to 64 years, but over one-half were operated on in the second or third decade (Table II).

The 158 operative procedures are summarized in Table III. There were 99 operations for appendicitis, 24 for gallbladder disease, eight pelvic laparotomies, five stomach operations, two nephropexies, nine thoracic operations, one repair of a rectovesical fistula and 11 operations for bowel obstruction (eight in the small bowel and three on the colon). Excluded from this study are one thyroid, two perineal repairs, three hernioplasties and one parotid resection. Also excluded are those cases with visceral mal-rotation or those with visceral mal-position. The time of diagnosis, placement of incision, and the location of pain

SURGERY IN SITUS INVERSUS

TABLE III.—*Operative Procedures*

I. Operations on the appendix (96 cases operated on).....	99
Appendectomy.....	77
Drainage of appendical abscess.....	3
Procedure not clear.....	5
Exploration, appendix not found.....	14
II. Operations on the biliary tract.....	24
Cholecystectomy.....	17
Cholecystectomy, removal of common duct stones.....	4
Cholecystostomy, removal of common duct stones.....	1
Cholecystostomy.....	1
Congenital absence of gallbladder, removal of common duct stones.....	1
III. Operations on the stomach.....	5
Gastric resection for carcinoma.....	1
Gastro-enterostomy for carcinoma.....	1
Closure of perforated duodenal ulcer.....	1
Gastro-enterostomy for gastric ulcer.....	1
Gastric resection for gastric ulcer.....	1
IV. Nephropexy.....	2
V. Bowel obstruction.....	11
Adhesive small bowel obstruction.....	2
Congenital obstruction duodenal-jejunal junction.....	1
Accessory spleens with partial small bowel obstruction.....	1
Volvulus of the small bowel.....	1
Ileostomies in case of ileocecal T. B. with bowel obstruction.....	3
Resection of inflammatory tumor of sigmoid.....	1
Exploration for congenital stenosis of sigmoid.....	1
Diverticulitis sigmoid.....	1
VI. Pelvic laparotomies.....	8
Uterine suspension, etc.....	3
Oophorectomy.....	2
Ectopic pregnancy.....	1
Hysterectomy.....	2
VII. Thoracic operations.....	9
Lobectomy for bronchiectasis (4 patients).....	6
Multiple pneumothorax.....	1
Pleuroscopy.....	1
Removal of bullet.....	1
VIII. Rectovesicle fistula.....	1
Total number of cases.....	144
Total number operations.....	159
(One case had a gastro-enterostomy and cholecystectomy at same operation) Minus.....	1
Total number of operations.....	158
Other Extra-Cavity Operations not included in Review	
IX. Perrineorrhaphy and colporrhaphy.....	2
X. Thyroidectomy.....	1
XI. Parotid tumor.....	1
XII. Hernioplasty.....	3

are summarized in Tables IV, V and VI. There is a discrepancy in the figures because one patient had both a cholecystectomy and gastroenterostomy performed at the same time and therefore is considered in both the gallbladder and stomach groups.

APPENDICITIS

Appendectomy was performed in 77 cases, appendicial abscesses drained in three, and the abdomen closed without finding the appendix in 14. In three of the latter, the appendix was removed later by a second operation. In five cases the operative procedure was not clearly stated. The pathology as given

TABLE IV.—*Time of Diagnosis.*

Diseases of	Number Operation	No Data	Diagnosis Before Operation	Diagnosis During Operation	Diagnosis After Operation	Total	Operation Not Accomplished
Appendix.....	99	26	39	24	10	99	13
Gallbladder.....	24	1	16	6	1	24	0
Pelvic laparotomy.....	8	2	3	3	0	8	0
Stomach and duodenum.....	5	0	3	2	0	5	0
Nephropexy.....	2	1	1	0	0	2	0
Thoracic operations.....	9	0	8	1	0	9	0
Intestine and colon.....	11	0	1	5	5	11	2
Rectovesicle fistula.....	1	0	0	0	1	1	0
Total.....	159*	30	71	41	17	158	15

* 158 operations on 144 patients. In one case a gastroenterostomy and cholecystectomy was performed at one laparotomy.

TABLE V.—*Placement of Incisions.*

Diseases of	Number Operations	No Data	Incorrect Incision	Correct Incision	Second Incision	Second Operation	Total No. Incisions
Appendix.....	99	34	27	35	6	3	105
Gallbladder.....	24	6	5	13	1	0	25
Pelvic laparotomy.....	8	0	0	8	0	0	8
Stomach and duodenum.....	5	2	0	3	0	0	5
Nephropexy.....	2	0	0	2	0	0	2
Intestine and colon.....	10	1	3	5	1	2	12
Thoracic operations.....	9	0	1	8	0	0	9
Rectovesicle fistula.....	1	0	0	1	0	0	1
Total.....	158	43	36	75	8	5	167

revealed that 34 had acute uncomplicated appendicitis, nine had appendicitis with peritonitis, six had appendicial abscesses and 23 were questionable, having been classified as chronic, interval, normal* or recurring. No information is available on the remainder.

The diagnosis of situs inversus was made before surgery in 39 cases, during surgery in 24 and several days after surgery in 10.

The point of maximum pain was located in the left lower quadrant in 32 cases, in the right lower quadrant in 21 and throughout the lower abdomen in four.

* In one of these cases, reported by Michael,⁹⁰ an adherent appendix was removed from the sac during the repair of a left indirect inguinal hernia.

SURGERY IN SITUS INVERSUS

A left-sided incision was made in 30 cases (four left McBurney's), a median incision in five and a right-sided incision in 27 (eight right McBurney's). A second correctly-placed incision was made in six cases. Of those with an original right McBurney incision, a second incision was made in four, the original incision enlarged in three and the abdomen closed without finding the appendix in one.

GALLBLADDER

All 24 patients had definite gallbladder disease, 15 had gallstones and six had common duct stones. Cholecystectomy was performed in 21, cholecystostomy in two and stones removed from the common duct in seven. The pain

TABLE VI.—False Pain Projection in Appendicitis and Gallbladder Disease
Location of Pain, Placement of Incision and Time of Diagnosis

Left-Sided Appendicitis												
Incision						When Diagnosis is Made						
Location Pain	No. Cases	Right Side	Left Side	Mid- Line	Not Stated	Second Inci- sion	Second Opera- tion	Before Opera- tion	During Opera- tion	After Opera- tion	Not Given	Total
Pain—left.....	32	2	25	1	4	0	0	25	4	0	3	32
Not localized....	4	3	1	0	0	1	0	2	2	0	0	4
Right.....	21	16	2	2	1	3	2	4	13	4	0	21
Not stated.....	39	6	2	2	29	2	1	5	5	6	23	39
Total.....	96	27	30	5	34	6	3	36	24	10	26	96

Left-Sided Gallbladder Disease												
Pain—left.....	16	2	9	1	4	1	0	14	2	0	0	16
Midline.....	1	1	0	0	0	0	0	0	1	0	0	1
Right.....	2	1	0	1	0	0	0	1	1	0	0	2
Not stated.....	5	1	2	0	2	0	0	2	2	0	1	5
Total.....	24	5	11	2	6	1	0	17	6	0	1	24

was located in the left subcostal area in 16, and in the midline in one and under the right rib margin in two. The diagnosis of situs inversus was made before operation in 17, during operation in six and after operation in one. A correct left-sided incision was made in 11 cases, a midline incision in two and a right-sided incision in five. A second incision was required in only one case. One author suggests that exposure of the common duct was easier technically through a right-sided incision. The case reported by Beck⁷ is of interest because the symptoms were first thought to be due to ptosis of the left kidney. Cholecystectomy was finally performed ten days after an unsuccessful left-sided nephropexy.

BOWEL SURGERY

Three patients had lesions of the colon. Fairchild³⁶ reports the case of a 30-year-old female who was operated on for appendicitis through a right rectus incision. An "inflammatory tumor" of the sigmoid was found lying in the right lower quadrant and was resected. Total visceral transposition, however,

was not discovered until two years later when roentgen-ray studies were made of the gallbladder.

Boeminghaus¹⁶ case is of special interest because, although a total visceral transposition was present, the cecum was in the right lower quadrant as a result of a super-imposed mal-rotation of the bowel. The patient, a 16-year-old male, had a congenital stenosis of the sigmoid and died after ileosigmoidostomy and appendectomy. The diagnosis was confirmed by autopsy.

Lyons⁸² reported the case of a 63-year-old female with right-sided symptoms suggesting appendicial abscess. Operation through a right-sided incision revealed total visceral transposition and diverticulitis of the sigmoid. It is significant that, although most of the pain in this case was on the right, there was some discomfort in the left flank, probably the result of referred phenomenon, a condition which will be discussed in detail later.

The two cases reported by Bryan¹⁹ and Maguire,⁸³ both with total transposition, were successfully operated on for adhesive obstruction of the terminal ileum.

In Oehlecker's⁹⁶ case a massive small bowel resection was performed for volvulus. At operation, performed through a midline incision, the patient was found to have a partial transposition with the stomach on the right, the liver and spleen both on the right and the cecum on the left.

Moore⁹² performed three successive ileostomies on a patient with a small bowel obstruction due to ileo-cecal tuberculosis. The author states "adequate drainage at first would probably have made little difference, but had we followed the suggestion from finding the heart on the right side and made an incision and enterostomy on the left, our chances would have been better."

Martinez⁸⁷ encountered a 21-year-old male who had a "tumor" in the right lower quadrant. Total situs inversus was discovered and the abdomen was opened through a right-sided incision. The "tumor" was found to be an accessory right-sided spleen with a long pedicle which had produced an obstruction of the ileum.

Tondury and Wissler¹²⁵ reported a case of a ten-day-old infant who was explored because of a mechanical obstruction at the duodeno-jejunal juncture caused by a partial transposition of the stomach and colon.

It is of interest that in this series of 11 cases, three had other congenital anomalies which played a role in the terminal illness.

THORACIC OPERATIONS

Nine operations were performed on seven patients. Smith and Horton¹¹⁵ removed a bullet from the chest of a man who failed in his suicide attempt because he aimed a gun over the usual left precordial area. Vargas¹²⁸ performed repeated pneumothorax treatments on a patient with tuberculosis and LeLong and Meyer⁷⁵ pleuroscoped such a patient with an aortic aneurysm.

Six pulmonary lobectomies were performed on four patients with bronchiectasis. These cases were reported by Ingraham,⁶² Flick,⁴⁰ Lillianthal,⁷⁹ Adams and Churchill.² The fact that 3 per cent of the patients in this series required lobectomy for bronchiectasis conforms with the opinion expressed by Adams

SURGERY IN SITUS INVERSUS

and Churchill that in these individuals there is an increased incidence of bronchiectasis (Kartegner's Syndrome). The ease with which the transposition can be overlooked is emphasized by one case in which the incision was made on the wrong side of the chest in spite of repeated chest roentgenograms and physical examinations before surgery. This error resulted from a failure to note the film marking on the roentgen-ray plate.

PELVIC LAPAROTOMIES

In the group of pelvic laparotomies there were three uterine suspensions, two hysterectomies, one ectopic pregnancy and two oophorectomies. The appendix was removed in three and a perineorrhaphy performed in one. All operations were performed through a low midline or Pfannensteel incision. The transposition was recognized before surgery in only three instances but the error did not seriously interfere with the surgical procedure.

STOMACH OPERATIONS

Five patients were operated on for diseases of the stomach. One of these¹⁸ was seen personally in consultation. The patient, a 60-year-old male, had a large prepyloric carcinoma of the stomach. The visceral transposition was recognized preoperatively by physical and roentgen-ray examinations and confirmed by laparotomy. As far as we could determine this was the first case to be recorded in which a successful right-sided subtotal gastric resection had been performed in the presence of this anomaly.

Allen³ reported the case of a prepyloric carcinoma in a 30-year-old male who died three weeks after gastro-enterostomy; and Kapustin successfully performed a Billroth I type of partial gastrectomy on a 57-year-old male with a large perforating gastric ulcer.

Kelly⁶⁸ performed a cholecystectomy and gastroenterostomy on a 40-year-old female who had both a gastric ulcer and gallstones and King⁷⁰ successfully closed a perforated duodenal ulcer in a 46-year-old Negro. The presence of situs inversus did not interfere with treatment in any of these cases.

DISCUSSION*

An error in diagnosis occurred in approximately 45 per cent of these cases. The transposition was recognized before surgery in 71 (55 per cent) and during surgery in 41 (32 per cent). In 17 (13 per cent) because of the bewilderment of the surgeon the condition was not recognized even at the time of operation. In these, the diagnosis was finally made at a later date by roentgen-ray studies.

An incorrect surgical incision was made in 36 cases (31 per cent) and in 15 the abdomen was closed without accomplishing the operative procedure. In five of the latter the disease process was corrected by a second operation performed after a correct diagnosis had been made.

Undoubtedly many of these errors were made because the examining physician, not suspecting the visceral transposition, misinterpreted the signs

* In determining percentages those cases without available information are excluded.

and symptoms. This was particularly true in the cases of those individuals with appendicitis, a disease usually considered a surgical emergency and frequently operated on at odd hours of the day, often after only a cursory physical examination. Although the condition can be recognized by physical examination alone, statistics indicate that it is usually overlooked unless roentgen-ray studies are made.

FALSE PAIN PROJECTION

An added diagnostic difficulty arises from the fact that many of these individuals complain of pain on the side of the body opposite to that of the diseased organ. This phenomenon has been described in the literature but as yet has not been clearly explained. Pol,⁹⁹ in a smaller series, found that 50 per cent of the patients with left-sided appendicitis complained of pain on the right.

In this series out of 96 patients who were operated on for appendicitis, information concerning the location of pain was available only in 57 instances. The pain was located on the right in 21, on the left in 32 and throughout the lower abdomen with no lateral localization in four.

Of the 21 cases with pain on the right, three were classified as chronic, interval or recurrent and three had other pathology to account for the pain; this leaves 15 which are probably examples of false pain projection (Table No. VI). In at least nine of these there was some discomfort in both lower quadrants, although the point of maximum pain was on the right. In Lawrence's case,⁷³ the pain was "mostly on the right except on deep pressure when there was more on the left." Mason and Baker's⁸⁶ case had generalized pain and soreness on the left which shifted to the right.

Of the 32 cases with pain on the left, six were questionable being classified as chronic, interval or recurrent. Acute appendicitis was present in 14, gangrene in four, abscess formation in three and peritonitis in five. Five had typical epigastric distress which localized in the left lower quadrant and five had pain in both lower quadrants more marked on the left.

If this data is rearranged we note that of the 45 cases with definitely proven appendicitis, at least 18 had pain in both lower quadrants. The pain was most marked on the right in nine of these and on the left in five. In four there was no lateral localization. The pain was said to be limited to the right side in only six cases and to the left side in 21.

Because of the paucity of available information in these case reports, it is impossible to determine accurately the true clinical picture of appendicitis in these anomalous individuals. There is no doubt, however, that it is variable and confusing.

VISCERAL PAIN PERCEPTION

The mechanisms of visceral pain perception are not clearly understood—apparently there are three types.^{102, 132, 15}

- (1) Referred pain perception as described by Head and McKenzie.
- (2) Direct visceral pain perception.
- (3) Direct somatic pain perception.

SURGERY IN SITUS INVERSUS

TABLE VII.—*Left-Sided Appendicitis with False Pain Projection to the Right.*

Author	Sex and Age	Pathology	Symptoms	Incision	Time of Diagnosis
Rush ¹⁰⁴	M—18	Acutely inflamed retro-cecal appendix	Ill 48 hours with general cramps, nausea, and vomiting. Pain localized in the right lower quadrant. Tenderness right lower quadrant.	Right rectus	Suspected before operation
Hemple ¹¹	F—9	Acute appendicitis. Inflammatory changes in the middle third.	Ill 1 day. General abdominal pains which localized in the right. All pain spontaneous as well as pressure in the right lower quadrant.	Right pararectal	Operation
King ⁷⁰	F—20	Acute appendix covered with fibrin	Ill 4 days. Generalized abdominal pain in both lower quadrants more severe on right.	Low midline	Before operation
Uehara ¹²⁷	F—28	Acute plegmonous appendix	Symptoms located on the right.	Right rectus	Operation
Block and Michael ¹⁸	F—26	Acute catarrhal appendix, 4 month pregnancy. Acute appendix inflamed.	Ill 4 hours. Pain in the right lower quadrant. Slight general rigidity. Extreme tenderness in right iliac region.	Right McBurney (enlarged)	Operation
Pol, Z. ⁹⁹	F—8	Acute appendicitis	Pain in the right lower quadrant. The constant localization of pain on the right suggested normal location of the viscera.	2 incisions right McBurney and left McBurney	Operation
Mason and Baker ⁸⁶	F—13	Acute appendicitis	Ill 24 hours. General abdominal pain with soreness in the left lower quadrant which shifted to right. Tenderness over entire abdomen more intense on right.	Left para-median	Operation
Lawrence ⁷³	F—19	Left-sided appendicitis	Ill 12 hours. Pain was mostly on the right side except on deep pressure when there was more on left.	Right rectus	Confirmed at operation
Lucente ⁴⁰	M—16	Appendicitis. Appendix injected high on left	Generalized abdominal pain in both lower quadrants with tenderness and pain in right lower quadrant.	2 Incisions. Right McBurney Midline	Operation
Scopinaro ¹¹¹	M—30	Acute appendicitis (not proved)	Acute pain in both lower quadrants, most marked on right. Clinically thought to be appendicitis. Appendix not found at emergency operation but an adherent appendix removed six months later.	2 operations. Right Davis and Midline	Operation
DePol ¹⁰	M—35	Appendicitis	Pain around the navel radiating to the right lower quadrant. Some pain on left, but most severe on right.	Left para-rectal	Before operation
Bertone ¹³	F—13	Acute appendicitis	Acute pain in the lower abdomen, right. Upon palpation the pain was more rectus conspicuous on the right.	Right rectus	Operation

TABLE VII.—*Left-Sided Appendicitis with False Pain Projection to the Right* (Continued)

Author	Sex and Age	Pathology	Symptoms	Incision	Time of Diagnosis
Simons ¹¹⁴	F—22	Acute appendicitis. General peritonitis	General low abdominal pain, more marked on right.	Right rectus; abdomen closed. Appendix not found	Operation
Pool ¹⁰⁰	M—14	Appendicitis with peritonitis	General abdominal pain, tenderness and rigidity; more marked on right.	2 incisions right para-median; left McBurney	Operation
Belmes ¹¹	F—17	Pain right lower quadrant. Probable acute appendicitis	Pain right lower quadrant.	Right rectus. Appendix not found	Operation

Left-Sided Gallbladder Disease with Right-Sided Pain

Gonzales ⁴⁸	F—23	Cholecystitis	Indigestion. Pain in the upper abdomen radiating under the right rib margin.	Right Judd incision	Operation
Wood and Blalock ¹³³	F—46	Cholecystitis and lithiasis	Pain in the upper abdomen radiating to the right flank and back.	Median	Before operation

In appendicitis occurring in normal individuals the pain is usually first perceived as a vague, mild, generalized epigastric distress which finally localizes in the right lower abdomen. Some authors believe that this right-sided pain is due to referred phenomenon (type 1), while others believe it is the result of direct visceral perception (type 2). As the disease progresses and the parietal peritoneum becomes involved, direct somatic perception may occur.

Evidence suggests that in situs inversus, although the viscera are transposed, the component parts of the nervous system are not reversed.²⁴ Therefore, regardless of the position of the viscera, it is reasonable to assume that their innervation will remain the same. It is for this reason that Block and Michael¹⁵ agree with Kuntz that in appendicitis in situs inversus "*the referred phenomenon ought to be localized on the right side.*"

It is suggested in this report that the location of visceral pain in situs inversus might shift from one side of the body to the other, depending on the nervous mechanism which dominates that particular stage of the disease. Right-sided pain may be due to referred phenomenon and left-sided pain to direct visceral or somatic perception. In appendicitis, the pain may start with the usual epigastric distress which shifts temporarily to the right lower quadrant as the result of false projection but finally, as the disease progresses, localizes in the left lower quadrant over the diseased organ. At times during the course of the illness the patient himself might conceivably be confused as to the location of the pain because of the involvement of both mechanisms.

Little is said about the character of abdominal tenderness and related physical findings. Some of the cases are described as having "tenderness in both lower quadrants, more marked on the right" or "more marked on the left."

Others are said to show general tenderness with no lateral localization. Lawrence's⁷³ case had more pain on the right but more tenderness on the left. In the cases of Block and Michael¹⁵ and Curt Hempel⁵⁵ tenderness as well as pain was said to be on the right. The disease in both of these was early and the transposition was not discovered until the abdomen was opened. It seems logical to assume, however, that the maximum point of tenderness should be located directly over the diseased organ but from the available information it is impossible to determine whether in the early stage of the disease pain produced by left-sided pressure might be projected to the right side.

In order to clarify this confused clinical picture, the suggestion is made that surgeons who in the future are privileged to see a patient with situs inversus and appendicitis report a detailed description of the history and physical findings with the points of this discussion in mind.

SUMMARY

In a collective review of the literature, an analysis is made of the available data in 144 cases of situs inversus in which 158 surgical operations were performed.

There were 99 operations for appendicitis, 24 for gallbladder disease, five stomach operations, eight pelvic laparotomies, two nephropexies, 11 operations of the large and small bowel, one repair of rectovesical fistula and nine thoracic operations including six lobectomies for bronchiectasis.

The difficulty in recognizing situs inversus is emphasized by the fact that an incorrect preoperative diagnosis was made in approximately 45 per cent of the cases and as a result in 31 per cent an incorrect surgical incision was made. False projection of pain to the opposite side of the body was present in at least 33 per cent of the cases of left-sided appendicitis and 8 per cent of the cases of left-sided gallbladder disease.

Considerable confusion exists regarding the phenomenon of false pain projection in patients with this anomaly. Accepting the theories of Kuntz and reasoning along the lines of Block and Michael, the suggestion is made that patients with appendicitis may have pain in both lower abdominal quadrants. In the early stages of the disease pain may be projected falsely to the right side, but as the disease progresses true localization will occur on the left over the diseased organ.

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FACTORS IN THE MORTALITY OF THE RUPTURED APPENDIX*†

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In a report¹ compiled for the years 1931-1937 inclusive and representing a study of 1412 consecutive cases of all types of appendicitis it was found that those cases complicated by perforation had a mortality of 15.3 per cent. The unruptured group carried a mortality of less than 2 per cent during this period. Any appreciable reduction in overall mortality must therefore be directed toward the perforated group.

The material in this report is derived from the perforated cases which were admitted to the hospital from 1942-1947 inclusive. The year 1942 was chosen as a starting point because the general use of the sulfonamide drugs was instituted in that year in this hospital. A total of 183 cases of perforated appendices were found in the records and in addition 65 cases of gangrenous appendicitis with local peritonitis were analyzed in this six-year period. All cases were admissions to the Muhlenberg Hospital which is a general hospital in a suburban community with a rated capacity of 330 beds.

It can be seen from the two tables submitted that there has been a reduction of 6.6 per cent in the perforated group for the years 1942-47. This decrease in mortality is probably not due to any single factor in the management of the appendicitis problem but it is difficult to escape the conclusion that the sulfonamides and antibiotics played a major role in effecting this reduction. Other factors which might be mentioned include:

- (a) Better appreciation of the problems of fluid requirements and vitamin deficiencies.
- (b) Improved methods of anesthesia.
- (c) Advent of tube decompression of the intestinal tract.
- (d) Educational methods to acquaint the patient with the danger of delay, catharsis, etc.

One hesitates to make any definite statement concerning the effects of early ambulation on the mortality rate inasmuch as it has been utilized only in the non-perforated group in this hospital.

Other published reports have generally shown a waning mortality in this disease in recent years. Tashiro and Zininger² in a review of 936 cases at the Cincinnati General Hospital found that the mortality in the perforated group was 13.77 per cent between the years 1939 and 1943. This is to be com-

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MORTALITY OF RUPTURED APPENDIX

pared with their previous figures of 17.2 per cent (1934-38) and 33.9 per cent between 1915 and 1934. Schullinger³ studied results at the Presbyterian Hospital, N. Y., and classified the cases complicated by perforation into three main groups which he defined as the acute progressive fibrino-purulent peritonitis, the acute diffuse peritonitis and the peritonitis with abscess. In the years 1941-46, 10 deaths occurred which gave them an average mortality of 6.6 per cent for the three groups mentioned.

TABLE I.

Year	Perforated	Deaths	Mortality	Gangrenous	Deaths	Mortality
1942	33	2	6.0%	5	0	0
1943	20	3	15.0%	14	0	0
1944	27	4	15.0%	12	0	0
1945	32	4	12.5%	10	0	0
1946	45	2	4.4%	17	0	0
1947	26	1	3.8%	7	1	14.2%
Totals	183	16	8.7%	65	1	1.5%

Average mortality for ruptured cases 1942-47 is 8.7%.

Average mortality for acute gangrenous cases 1942-47 is 1.5%.

TABLE II.

Years	Perforated	Deaths	Mortality
1931-1937	165	26	15.3%
1942-1947	183	16	8.7%

Meyer *et al.*⁴ reported on their experience at the Cook County Hospital in Chicago. In the two years 1944 and 1945 they studied 136 perforated cases and found the mortality to be 13.9 per cent.

Kaufman and Mersheimer⁵ tabulated 92 ruptured appendices from June 1940 to December 1941 at the Metropolitan and Flower Hospitals in New York City. The sulfonamides had been used in the therapy and with 10 deaths their mortality rate was established at 10.8 per cent.

The highest mortality occurred in the 7th and 8th decades as would be the normal expectancy. The appendix at this age has undergone considerable fibrosis with a diminution of blood supply and consequent inability to build up local defenses against the infection. The devitalized appendix is also more prone to perforation. The mortality in the 4th decade is surprising when it is noted that it is much lower in the 5th and 6th.

CATHARSES AND ENEMATA

Since the publication of the last series the public has been informed by various means that active purgation is a dangerous course in the presence of abdominal pain. Although the figures in this respect are not entirely conclusive due to the failure of accurate recording on the charts, a tabulation showed that 8.1 per cent of the perforated cases had taken a cathartic of some sort previous to admission. This figure is a marked decrease from the 23 per cent

of the former series. Thirteen per cent had received a rectal irrigation as compared to the previous figure of 10 per cent. There seems to be no definite hazard from rectal irrigation when it is not massive and when the diagnosis of appendicitis is uncertain.

DRAINAGE

No flat statement can be made from our figures as to the value of drainage. In the years 1942-45 100 per cent of the cases were drained, but in the next two years (1946-47) there was a drop in the cases drained to approximately 82 per cent. This would seem to indicate that the operators were beginning to doubt the efficacy of drainage when the peritoneum was contaminated.

Jackson⁶ has recently advocated the principle of nondrainage in the perforated appendix and cites 15 cases of perforated appendicitis in which the

TABLE III.

Age Distribution: Age	No. Cases	Deaths	Percentage Mortality
0-1 year	0	0	0
1-9 year	29	1	3.4
10-19 year	77	5	6.5
20-29 year	26	0	0.0
30-39 year	29	0	0.0
40-49 year	33	6	18.2
50-59 year	29	1	3.4
60-69 year	14	0	0.0
70-79 year	7	2	28.5
80-89 year	4	2	50.0

appendix was removed and closure was done without drainage. One secondary abscess occurred which required drainage but there was no death in this series. He stressed the disadvantages of prolonged drainage with attendant wound infection, adhesions, fistulae, herniae, *etc.*

On the other hand Schullinger³ advocates intraperitoneal drainage under the following conditions:

- (a) Abscess.
- (b) Presence of necrotic tissue which cannot be readily excised.
- (c) Appendix not removed.
- (d) Extensive exposure of retroperitoneal tissue.
- (e) Insecure ligation of the stump.

HOSPITAL DAYS

There has been some decrease in the length of the hospital stay for the perforated cases. The average length of time for the years 1931-37 amounted to 23.2 days while the recent series averaged 20.7 days.

A greater decrease in hospital days was anticipated. This small decrease might be explained on the basis that some desperately ill patients underwent a prolonged convalescence who might have terminated fatally if improved methods of therapy had not been available.

MORTALITY OF RUPTURED APPENDIX

As has been previously stated those perforated cases who ran a febrile course and leukocytosis were not encouraged to practice early ambulation until their fever had subsided. Whether early ambulation would have decreased their hospital stay is debatable.

SULFONAMIDE — ANTIBIOTIC THERAPY

Approximately 88 per cent of the perforated cases had implantation of the powdered sulfa drug in the peritoneal cavity at the time of operation. The amount of drug used varied greatly among the different operators with an average of from 3 to 10 Gm. Some form of the sulfa drug was given orally in 41.3 per cent of all cases while 43.7 per cent received it intravenously buffered with sodium lactate. The intravenous dose was a subject of some debate but many operators have felt that if it was to attain an adequate blood level as much as 7.5 Gm. should be administered over a 24-hour period. No serious complications have resulted from the use of this dosage.

Penicillin was first used in 1944. There was a rapid increase in this mode of therapy in the last three years when approximately three-fourths of all perforated cases received the drug. The intramuscular route has been favored over the oral or intraperitoneal route.

The use of streptomycin has been very limited. Of three cases in which it was used two recovered and one terminated fatally. It was used in conjunction with the two previously mentioned drugs which makes its evaluation difficult but there does seem to be a question whether the dosage of 600 mgs. per day was adequate.

THE ROLE OF CONSERVATISM

As a general rule laparotomy was performed when the diagnosis of appendicitis was established. A delay was indicated if the patient was dehydrated markedly or in a near moribund state.

An exception to this rule was carried out in a selected group of patients who upon admission presented a palpable right lower quadrant mass and who seemed to have walled off their perforation. On the assumption that surgery would possibly interfere with the local defense mechanisms set up by the body, these patients were watched carefully for change in size of the mass. Therapy consisted of moderately heavy doses of sulfa drug, penicillin, streptomycin, intravenous fluids, sedatives, *etc.* This regimen was carried out on a total of eight patients without any mortality which would seem to justify its continuance in this type of case. On discharge the patient is warned as to probable recurrence and urged to return at the expiration of four months for appendectomy.

The experience of Meyer *et al.*,⁴ at Cook County Hospital has indicated that whenever a mass is definitely palpable in the region of the cecum operative interference carries a higher mortality. They cited 75 cases which they felt represented abscess formation. Twelve of these patients were subjected to operation with an eventual mortality of 8.5 per cent while the remaining 63

patients were treated by non-operative means and carried the lower mortality of 3.1 per cent. It should be noted that these figures are drawn from the years 1944 and 1945.

THE CHRONIC APPENDIX

An incidental finding in this review was the infrequency of the diagnosis of "chronic" appendicitis. Whereas in the series from 1931-1937 the ratio of acute and chronic appendices was about one to one, it is now found that the

TABLE IV.

Complications	Number of Cases
Dermatitis presumably due to sulfonamides.....	2
Fecal fistula.....	6
Grossly infected wound.....	6
Intestinal obstruction.....	6
Diabetes mellitus (diagnosed pre-operatively).....	3
Bronchopneumonia.....	3
Pulmonary embolus.....	2
Ruptured appendix in inguinal hernia sac.....	1
Pregnancy (3 months).....	1
Evisceration.....	2
Atelectasis.....	1
Hemorrhage from ileostomy.....	1

pathologic diagnosis of an acute process occurs in the ratio of eight to one of the "chronic" type. The pathologic picture of the chronic appendix has never been clear cut. Soreness in the right lower quadrant along with gastro-intestinal complaints such as gas and constipation have often made up the clinical picture, but there is a growing tendency to believe that the history should include the signs and symptoms of a more or less acute infectious process.

TABLE V.

Types of Incision	
1. Right rectus.....	230
2. McBurney.....	9
3. Extra peritoneal approach.....	2

TABLE VI.

Anesthesia	
1. Inhalation (general).....	195
2. Spinal.....	42
3. Pentothal sodium.....	1

INCIDENCE OF PERFORATION

Approximately 11 per cent of all patients with pathology in the appendix had perforation on admission. The 1931-1937 series also showed about this same incidence. It would be expected that the percentage of perforated cases would be lower due to better information possessed by the public as to the haz-

MORTALITY OF RUPTURED APPENDIX

ards of abdominal pain. Since the exact time of the perforation is not easy to deduce, it must be assumed that perforation may take place very early in the course of the disease and in some instances may even occur with the onset of symptoms.

COMPLICATIONS

Table IV lists only the major postoperative complications.

Of the six fecal fistulae listed in Table IV only two closed spontaneously, at the expiration of 21 and 23 days respectively. In the third case a fistula was present in the patient who expired on the 44th postoperative day. The fourth instance of a fistula persisted in a patient who had had an incision and drainage in the right lower quadrant. This fistula was explored and found to lead to the tip of the appendix and following removal of the appendix the fistula remained closed. The fistula in the 5th case required two operative attempts at closure. The first attempt was done 10 weeks following the original appendectomy and although the fistula was dissected down to its apparent terminus in a loop of the small bowel it failed to close. One year later it was again dissected out and remained closed. In the final case there is a question whether the fistula was a result of an appendiceal abscess. On admission to the hospital a stab incision was made and the abscess in the region of the cecum was thereby drained. Inasmuch as the drainage area did not remain closed but reopened in three weeks, further exploration was done and an extensive carcinoma of the cecum was found.

DEATHS

A summary of the deaths with the terminal diagnosis is given in Table VII.

Thus it can be seen from Table VII that 16 deaths occurred in the perforated group. In 11 of these the appendix was removed at operation while in four others a simple incision and drainage was done without appendectomy. One case had no surgery inasmuch as he was deemed too poor an operative risk on account of his cardiac condition. The diagnosis in this case was proved at autopsy. The one death in the non-perforated group occurred in a 19-year-old female. At autopsy on the 10th postoperative day a saddle type pulmonary embolus was found.

The largest number of deaths, six, occurred in the 40-50 year old group. The youngest casualty was a 9-year-old male, while the oldest were two individuals at the age of 84 years.

SUMMARY

1. A study of 183 cases of perforated appendices has been made. The majority of these cases received some form of chemotherapy and a mortality rate of 8.7 per cent has been determined for the whole group. This mortality rate represents a reduction of 6.6 per cent from a previous report of 165 cases not treated by chemotherapy published 10 years before.

2. The group in the late stages of perforation have seemed to do better with non-operative therapy. This group usually carry the highest mortality as compared with the group whose perforation is recent. The early perforated group as a rule are subjected to immediate operative therapy.

TABLE VII.

Deaths		Type of Surgery	Hos- pital Dur.		Terminal Diagnosis
Sex	Age		Days	Symp.	
1 F	51	Inc. and drainage	1	1	Cardiac decompensation—general peritonitis.
2 M	16	Appendectomy	6	1	General peritonitis with intestinal obstruction.
3 M	11	Appendectomy	1	1	General peritonitis.
4 M	84	Appendectomy	3	6	Appendix contained within an irreducible right inguinal hernia sac.
5 M	46	Appendectomy	5	5	Gangrenous cecum with general peritonitis.
6 M	44	No operation	3	7	General peritonitis (poor operative risk with history of coronary thrombosis).
7 M	49	Appendectomy	3	4	General peritonitis.
8 F	44	Inc. and drainage	2	3	General peritonitis.
9 M	42	Inc. and drainage	44	2	Broncho-pneumonia—fecal fistula—general peritonitis.
10 F	49	Inc. and drainage	4	5	General peritonitis.
11 M	75	Appendectomy	3	7	Hypertension—auricular fibrillation and general peritonitis.
12 F	10	Appendectomy	6	7	General peritonitis.
13 F	9	Appendectomy	1	2	General peritonitis.
14 F	70	Appendectomy	2	3	Diabetes mellitus and general peritonitis.
15 F	84	Appendectomy	2	3	Pulmonary embolism.
16 M	15	Appendectomy	7	3	Intestinal obstruction on 6th day with exploration on 7th day.
Gangrenous Case Mortality					
17 F	19	Appendectomy	10	1	Pulmonary embolus.

3. There is still opportunity for considerable improvement in the mortality figures herewith presented.

4. Removal of the nonperforated gangrenous appendix carries a low mortality even though some degree of local peritonitis may be present.

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NEUROFIBROMA:*

BENIGN INTRASPINAL-INTRATHORACIC "HOUR-GLASS" TUMOR WITH PARAPLEGIA

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INTRODUCTION

The therapeutic effect of roentgen rays on certain malignant tumors of the body is well known. Not infrequently mediastinal masses have been subjected to roentgen-ray therapy and the response to this treatment used as an indication of the malignancy of the lesion. Benign tumors show no diminution in size following such treatment and, as has been recently reported by Simpson,¹⁰ may be left for years without removal. Benign tumors may become malignant over the course of months or years and it is wise to remove or at least to biopsy all such tumors. Tumors involving the central nervous system, either the brain or spinal cord, however, should never be subjected to a therapeutic trial of roentgen-ray before biopsy or before decompression of the tumor.⁵ Both the spinal cord and the brain are enclosed in bone and irreversible changes may occur in these structures secondary to the pressure of tumors resulting from unnecessary delay in their removal. Furthermore, even known malignant tumors involving the central nervous system should not be radiated prior to operation since the swelling that results from therapy may be sufficient to cause permanent paralysis or death. Ward and Spurling¹¹ have taken exception to this rule in the surgical treatment of tumors of the third ventricle, advocating subtemporal decompression to reduce intracranial pressure and preserve vision and a trial of roentgen-ray therapy. Because of the high morbidity and mortality associated with removal of tumors in and around the third ventricle and because of the satisfactory response of some of these tumors to roentgen therapy, such a course may be justified, a subsequent surgical removal of tumors not responding to roentgen-ray being carried out in those patients deemed suitable for surgery. This is a highly specialized problem and does not vitiate the argument against the radiation of other tumors involving the central nervous system without preliminary histological verification.

Particular danger is inherent in the utilization of the roentgenographic appearance of a tumor as an index of its malignancy. The presumption that a tumor is incurable because of its size, appearance, and response to roentgen therapy may deprive an individual of the curative value of successful surgical therapy. The following case is illustrative of the potential danger and its successful outcome serves to further emphasize the need for careful consideration of these problems.

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CASE REPORT

S. F. Male. Age: 35. C. 15540.

Chief Complaint. Paralysis of legs, five months.

Family History. Non-contributory.

Past History. No previous nervous disorders. Mild chronic cough but no significant amount of sputum.

Present Illness. In August, 1947, this patient, a farmer, visited a travelling "Chest Clinic" where a roentgenogram was taken. He was told that he had a tumor in his chest and was advised to see his physician. He disregarded this advice but about one month later, in September, 1947, he first noticed slight weakness of his right leg. During

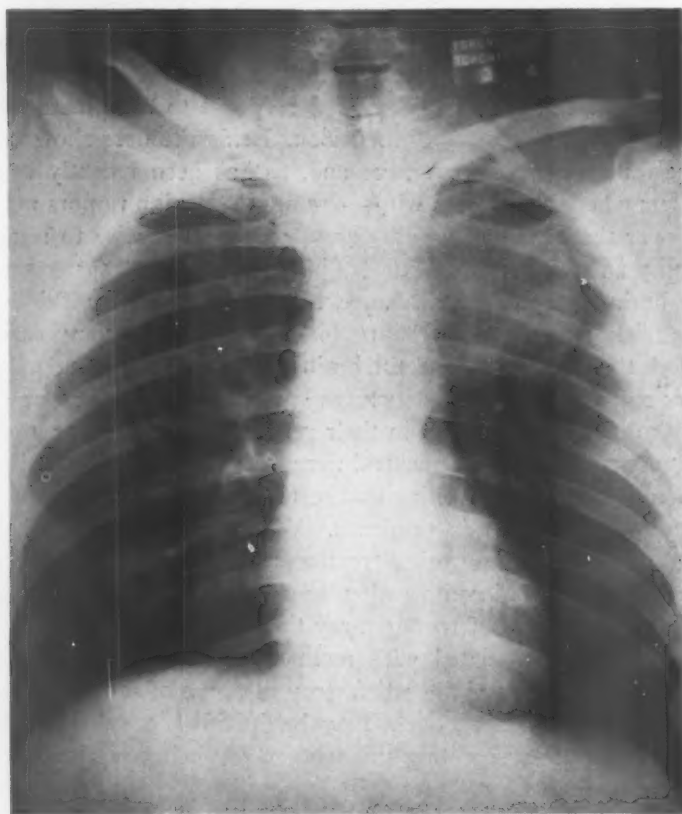


FIG. 1.—Roentgenogram of chest showing large rounded mass in left upper thoracic cavity.

the succeeding two months the weakness of the right leg became more severe and his left leg also became weak. In November, 1947, he had to stop work because of the weakness of his legs. He had had no pain in his back, chest or legs and at that time suffered no urinary hesitancy or incontinence.

The patient sought the help of a chiropractor but the treatments he received did not increase the strength in his legs. He then sought the help of a physician who in December, 1947, arranged for admission of the patient to the Toronto General Hospital. The patient, however, refused to keep this appointment and remained at home until February 21, 1948.

NEUROFIBROMA

During the two months prior to admission to the hospital he became completely bedridden and about one week before he finally came to the hospital, he became incontinent of urine and feces. A diagnosis of carcinoma of the lung was made and the patient was sent to the Radiotherapy Unit of the Toronto General Hospital.

There had been only a slight weight loss. He had had no hemoptysis.

Physical Examination. Temperature 98° F., pulse 80, respirations 16, blood pressure 128/80. The patient was well developed but thin. He was unable to sit or to stand because of weakness of muscles below his waist. The skin and subcutaneous tissues showed no abnormalities. Examination of the heart and lungs showed nothing abnormal.



FIG. 2.—Roentgenogram of thoracic spine and ribs. There is destruction of the head and neck of the fourth rib on the left with absence of the pedicle of the fourth dorsal vertebra on that side. Note trabeculated appearance of region in which rib is destroyed.

Neurologic Examination. Cranial nerves, spine and upper extremities normal. Sensory examination showed slight hypesthesia to pin-prick below the sixth thoracic dermatome level, this abnormality being more marked on the right than on the left. The exact upper limit of this was difficult to determine.

There was weakness of all muscles below the upper abdominal region and bilateral foot drop. Weakness was much more pronounced on the left than on the right. The knee and ankle responses were hyperactive on both sides and there was bilateral sustained ankle clonus. Babinski responses were positive bilaterally.

There was complete paralysis of bladder function, an indwelling urethral catheter with tidal irrigator being necessary, and the tone of the anal sphincter was absent.

Laboratory Data. Hemoglobin 98%; white blood count 11,000; urine examination normal; blood Wassermann negative; blood N. P. N. 42 mg. %.

Course in the Hospital. A roentgenogram of the chest disclosed a large discrete rounded mass in the left upper chest posteriorly measuring about 8.0 cm. in diameter (Fig. 1). There was destruction of the head and neck of the left fourth rib. Films of the thoracic spine showed loss of the pedicle of the fourth dorsal vertebra on the left side and erosion of the pedicles of the vertebrae immediately above and below the fourth vertebra (Fig. 2).

The patient was seen in consultation by the Surgical Service. It was felt that the appearance of the roentgenograms was unusual for a benign tumor. The tumor was considered to be a bronchogenic carcinoma with invasion of the fourth rib and secondary involvement of the spinal cord. Aspiration biopsy was advised. Two attempts at biopsy through needles specially designed for the purpose of biopsy were made, one on February 28, 1948, and one on March 9, 1948. Tumor tissue was not obtained in either biopsy.

On March 1, 1948, radiation therapy through anterior and posterior portals directed to the intrathoracic portion of the tumor was begun. This was continued to March 29, 1948, an estimated total of 3,000 roentgen units being delivered to the tumor.

During the period of roentgen therapy and immediately following it the patient showed a progressively more severe paraplegia so that by April 5, 1948, he was barely able to move his toes and could not bend his knees. A roentgenogram of the chest showed little or no change in the size of the tumor.

Arrangements were made for transfer of the patient to a home for incurables, it being felt that he was suffering from a malignant tumor which was inoperable and insensitive to roentgen-ray therapy. Before transfer of the patient to the home for incurables was effected, a consultation with the Neurosurgical Service was held. Operation was advised but because of the radiation skin reaction adjacent to the proposed operative site, this was delayed from April 12 to April 21.

Operation. April 21, 1948. A laminectomy of the second through the fifth dorsal vertebrae was done. Tumor tissue was encountered herniating through the laminae of the third and fourth dorsal vertebrae on the left side. The tumor was an encapsulated extra-dural mass and the intraspinal portion was completely removed. It extended out through the fourth left intervertebral canal into the chest, the neck of the tumor at this point measuring about 2-3 cm. The dura was opened and the spinal cord was normal except for a slight pressure defect at the point of maximum pressure from the extra-dural tumor. The dura was closed with silk and the wound was closed in layers with interrupted sutures of silk. The wound healed by primary intention and the patient noticed improvement in the sensation of the skin below the level of the tumor within three days after operation. Within two weeks the strength of the legs had increased greatly and the improvement was easily discernible. He began to suffer suprapubic discomfort and was discovered to have a vesicle calculus. This was removed through a cystoscope on April 29, 1948.

Operation. May 10, 1948. Through a left posterior thoracotomy incision, the left third, fourth and fifth ribs were partially resected and a large intrathoracic, extra-pleural, encapsulated tumor was removed. The portion of the spinal canal from which the intraspinal tumor had been previously taken was clearly visualized. All visible tumor was removed.

Postoperative Course. The patient made a satisfactory recovery from this operation and the wound healed satisfactorily. His neurologic improvement continued and by May 25, 1948, slightly more than one month after laminectomy, he was able to walk with help. Bladder and bowel control had been regained and were now practically normal. There was 30 cc. of residual urine on catheterization. Seven weeks after laminectomy the patient was able to walk alone with one cane and was discharged to a convalescent home for paraplegics for continued physiotherapy and training.

NEUROFIBROMA

August 30, 1948, three and one-half months after removal of the intraspinal portion of the tumor, the patient could walk normally and showed no objective weakness of his legs. Neurologic examination showed no sensory abnormalities. Knee and ankle jerks were slightly hyperactive, there was no ankle clonus, and the plantar responses were normal. He reported that sexual function was normal. He was at that time ready for discharge to his own home where he could resume light farm work.

Pathologic Report. Microscopic examination—the tumor was composed of cells which were fibroblastic in type, arranged in sweeping bands and occasionally in whorls. The tissue was moderately cellular but showed no evidence of malignancy.

Diagnosis. Benign neurofibroma or perineurial fibroblastoma (Fig. 3).

DISCUSSION

Hour-glass tumors located in part in the spinal canal and in part in the thoracic cavity are not common but there have been several reports of such

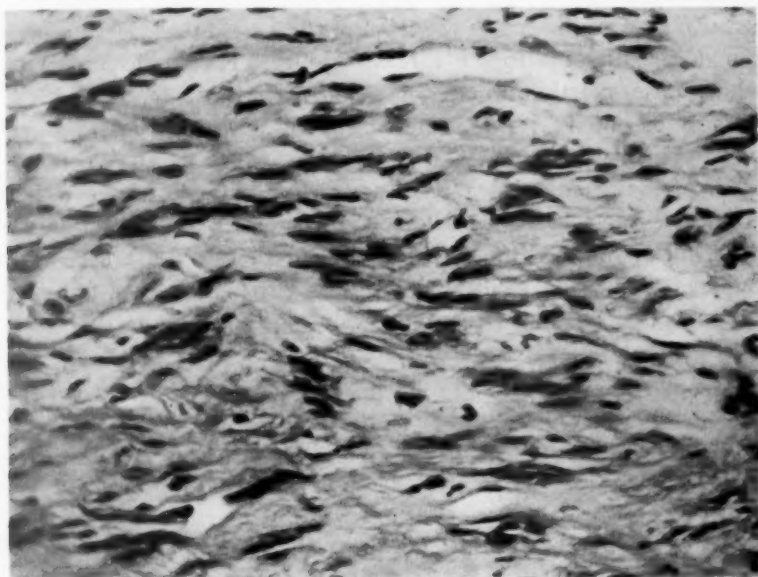


FIG. 3.—Photomicrograph of the tumor showing fibroblasts arranged in sweeping bands and occasional palisade formation. There is no evidence of malignancy.

lesions in the literature of the last two decades.^{2, 3, 4, 6, 7, 8} A number of different histologic tumors have been described but the majority of these tumors are benign. Most common of the lesions found in this particular location is the perineurial fibroblastoma or neurofibroma.

Several features of the case reported above are of particular interest and warrant consideration. The roentgenologic appearance of the tumor, particularly the involvement of the head and neck of the left fourth rib by what seemed to be a destructive process, is unusual for this type of tumor. A somewhat similar appearance was described by Carman and Davis¹ in 1924 in a patient who presented the roentgen-ray picture of a trabeculated cyst in one of the

lower dorsal vertebra. The lesion in their case was also a neurofibroma. No other cases have been found with roentgenographic features similar to this.

In 1941 Powles⁹ in New Zealand reported a case which has an interesting analogy to the case reported in this publication. The patient described by Powles was also paraplegic and presented with an intrathoracic as well as an intraspinal tumor. Because of the roentgen-ray appearance of the lesion, a diagnosis of carcinoma of the lung with metastases to the spine was made and no treatment was given. The paper did not contain reproduction of the roentgen-ray films. The progress of the lesion was so slow that those who were caring for the patient eventually questioned the diagnosis of a malignant tumor. By the time this question was raised, however, the individual was completely paraplegic and was not considered a suitable subject for surgery. He died of urinary tract infection and decubitus ulcers approximately 2½ years after the onset of his spinal cord symptoms. Post mortem examination showed a benign extramedullary neurofibroma at the level of the seventh cervical vertebra with extension of the tumor into the thoracic cavity. There was no evidence of malignancy. The exactly similar course of the patient reported herein was fortunately interrupted by the earlier suspicion of the benign nature of the lesion and the institution of surgical therapy.

In view of the profound degree of motor loss extending over a prolonged period of time, the rapid and almost complete recovery of motor, sensory, urinary, bowel and sexual function in this patient was not altogether anticipated and was particularly gratifying. Within four months he progressed from a state of severe paraplegia necessitating constant bed care to the recovery of such function that he was able to return to light farm work. It might be expected that his recovery will continue toward a normal state for some months and no recurrence is to be expected in view of the complete removal of what proved to be a benign lesion.

SUMMARY

1. A patient with a benign neurofibroma of the "hour-glass" type, involving the dorsal spine and the thoracic cavity has been presented.
2. The unusual roentgenographic appearance of this tumor has been demonstrated. This suggested a malignant tumor and an initial diagnosis of a bronchogenic carcinoma with invasion of the ribs and spine was made.
3. The patient was subjected to intensive radiation therapy directed to the intrathoracic portion of the tumor without perceptible effect.
4. Rapid recovery of the patient after complete surgical removal of the tumor has been described.
5. The danger of subjecting any tumor causing spinal cord compression to radiotherapy without biopsy has been re-emphasized.

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GUMMA OF THE LUNG

REPORT OF A CASE TREATED BY LOBECTOMY*

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ACQUIRED SYPHILIS OF THE LUNG is a rare disease. Wilson stated recently that only a small percentage of approximately 200 reported cases have been confirmed at autopsy.¹⁴ Several authors have subgrouped this disease according to its pathologic manifestations.^{1, 6, 9} The different classifications offered are not in complete agreement, but it is recognized generally that gumma of the lung is an unusual type of pulmonary syphilis.¹⁴

The treatment of gumma of the lung in the past has been medical. Arsenicals, iodides, bismuth compounds and mercurials have been given to affected patients with varied success. Penicillin has been used more recently.⁸ Since surgical excision of a pulmonary gumma has not been considered as a form of therapy, the following case is presented as an example of the operative treatment of this disease.

CASE HISTORY

J. W., No. 888615, a 39-year-old Negro male, entered the Presbyterian Hospital, New York, on October 27, 1947, because of left chest pain and cough of 5 weeks' duration.

History. He had a penile lesion at the age of 18 at which time he was given simultaneous injections into his hip and arm on three occasions. Three years before admission to the hospital his physician gave him 3 injections into his hip over a 6-day period because he was found to have a positive Wassermann.

He had no significant complaints until 5 weeks before admission when he had chilly sensations associated with pain in the lower left chest. This pain was dull in character, but it was aggravated by deep breathing and lying on the affected side. He soon developed a persistent cough productive of small amounts of yellow, non-foul, non-bloody sputum. His local physician noted an area of increased density in the lower lobe of the left lung by fluoroscopy. He made the diagnosis of virus pneumonia for which he prescribed cough medicine. This treatment produced temporary relief of the patient's cough, although the pain continued without increasing in severity. He began to feel moderately weak, and had occasional slight malaise. Over the 5-week period he lost 10 pounds in weight. He had no fever, chills or night sweats except at the onset of the illness.

Physical Examination. T-98.4 P-75 R-18 BP 115/80. The patient was a well-developed, well-nourished Negro male who was not in acute distress and showed no obvious signs of chronic illness. The following pertinent findings were noted. The examination of the eyes revealed nothing unusual. The teeth were grossly carious. There was no generalized glandular enlargement. The chest expanded symmetrically. Dullness was

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GUMMA OF THE LUNG

noted over the lower lobe of the left lung posteriorly, and tubular breathing with fine crackling inspiratory rales were heard over the same area. Both diaphragms descended equally and well. The liver, spleen and kidneys were not felt. A rectal stricture was noted on digital examination. The neurological findings were normal.

Laboratory Data. The urine was negative. The red blood cell count was 4.4 million; hemoglobin, 13.4 Gm. per cent; white blood count, 12,650 with 61 per cent polymorpho-nuclear leucocytes, 37 per cent lymphocytes and 2 per cent eosinophiles. A tuberculin test in 1:10,000 dilution was negative but positive in 1:100 dilution after 48 hours. The blood Kline and Wassermann tests were four plus to all antigens. The stool was negative for blood, ova and parasites. No acid fast bacilli were seen in the sputum, although pneumococci type VI were cultured from it. The blood was negative for cold agglutinins and the erythrocyte sedimentation rate was 130 mm. per hour. The Frei test was positive. The serum albumin was 4.3 Gm. per cent; globulin, 4.5 Gm. per cent; euglobulin 1.1 Gm. per cent; the blood urea nitrogen 17 mg. per cent; serum calcium, 10.8 mg. per cent; inorganic phosphorus, 4.8 mg. per cent; alkaline phosphatase 3.1 Bodansky units. The cephalin flocculation was negative and the thymol turbidity was 3 plus.

A lumbar puncture revealed an initial pressure of 165 mm. of spinal fluid. The micro-scopic examination of the fluid was not remarkable; the spinal fluid protein was 27 mg. per cent. The colloidal gold curve was flat and the spinal fluid Wassermann was negative to both the cholesterin and alcoholic antigens.

TABLE I.—Summary of Treatment, Procedures and Hospital Course (See Text)

Admitted		0
Attempted thoracentesis		2
Fluoroscopy		4
Lumbar puncture		6
Bronchoscopy		8
		10
		12
		14
		16
Decrease in size of pulmonary lesion noted for first time roentgenographically	Penicillin 400,000 U. Daily	18
		20
		22
		24
		26
No further reduction in size of lesion noted on films	Penicillin 1,000,000 U. Daily	28
		30
		32
Left lower lobe lobectomy	Lugol's Solution 25-30 cc. Daily	34
		36
		38
		40
		42
Discharged	Penicillin 400,000 U. Daily	44

Roentgenologic Findings. Roentgenograms of the chest taken on admission showed a well defined, lobulated area of increased density located posteriorly and medially in the left hemithorax (Fig. 1). The shadow appeared to occupy the dorsal apical and posterior basal divisions of the left lower lobe. The lung fields elsewhere and the heart were normal. It could not be determined whether this was a parenchymal lesion or a loculated collection of fluid.

A roentgenogram taken one week later showed no change in the shadow. Fluoroscopic examination at this time demonstrated movement of the lesion on respiration suggesting that the process was intrapulmonary. Spot films revealed considerable thickening of the pleura over the lateral aspect of the lower lobe on the left.

Course. The patient's only complaints on admission were persistent cough and mild left chest pain. To rule out a loculated pleural effusion, a needle was inserted into the left pleural cavity at an appropriate site, but no fluid could be obtained. On the fifth hospital day parenteral penicillin was administered to determine its effect on the size of

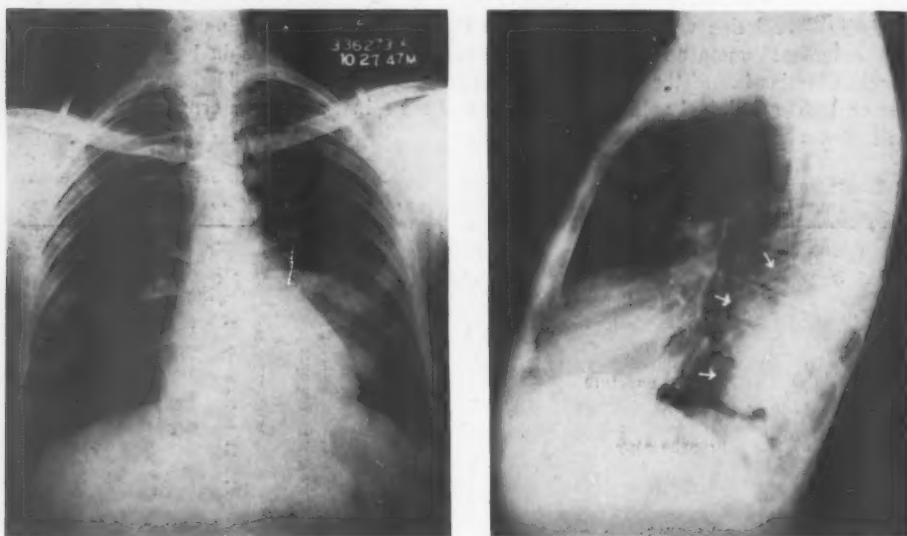


FIG. 1.—Gumma of lung, postero-anterior and left lateral projections.

Admission films (21 years following penile lesion) disclose a well-defined, lobulated, mottled area of increased density in the dorsal apical and posterior basal segments in the lower lobe of the left lung.

the chest lesion. Four hundred thousand units of the drug were given daily by the intramuscular route for 12 days. The clinical course of the patient continued to be benign. His cough and chest pain were less bothersome, but another roentgenogram at the end of this period was not significantly different than the one taken on admission. A bronchoscopic examination was performed on the 13th hospital day. The findings were normal except for slight, diffuse injection of the bronchial mucosa bilaterally.

Considering the history of lues, the positive serology, and the unusual contour of the pulmonary shadow, the diagnosis of gumma of the lung was contemplated. Accordingly, the dosage of the parenteral penicillin was increased to 1,000,000 units a day and this was administered for two weeks. Between 25 to 30 cc. of Lugols solution were also given daily over approximately the same period. The above treatment was instituted with two purposes in mind. It was thought advisable in the first place to treat his latent syphilis. Secondly, the pulmonary lesion could be studied by roentgen-ray examination for its response to therapy.

GUMMA OF THE LUNG

Roentgenograms of the chest were taken on the 19th hospital day and diminution in the size of the lesion was noted for the first time. A review of all the films showed that the volume of the lower lobe of the left lung was progressively decreasing with elevation of the left diaphragm. Roentgenographic studies nine days later, however, demonstrated no further decrease in the size of the lesion (Fig. 2).

Repeated physical examinations revealed essentially the same findings as noted on admission. The patient never had any significant changes in his temperature, pulse or respiratory rate. His cough and chest pain practically disappeared, and there was considerable improvement in his general well being.

After one month of medical treatment, surgical and medical consultants were of the opinion that the therapy instituted thus far had not produced a satisfactory response. The diagnosis had not been established definitely, and the presence of a neoplasm could not be ruled out. An exploratory thoracotomy and a left lower lobe lobectomy were performed, therefore, on the patient's 34th hospital day.

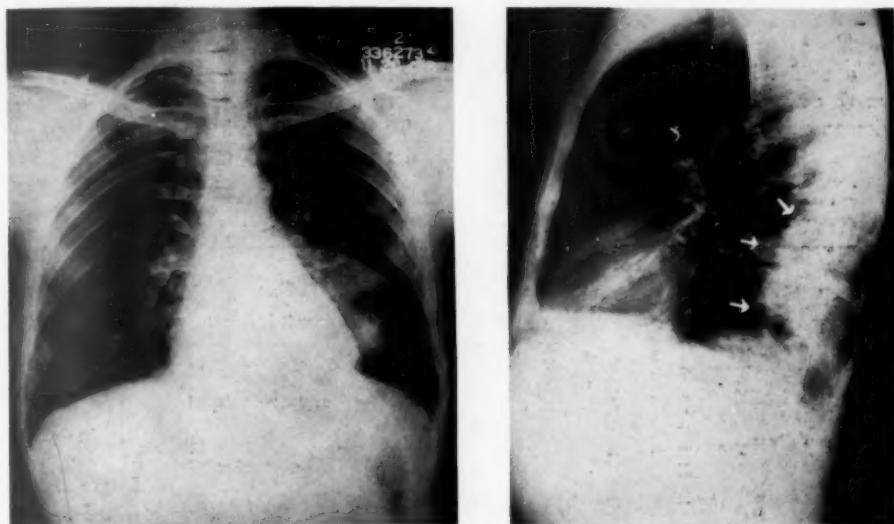


FIG. 2.—Gumma of lung, postero-anterior and left lateral projections.

Films made 30 days after films in Figure 1 (25 days after penicillin therapy) disclose a slight decrease in size of the mass, with the anterior border more sharply defined, as seen on the lateral film.

Diagnosis. Throughout this patient's hospitalization, studies were directed to determine whether the underlying pulmonary pathology was inflammatory or neoplastic, and most of the evidence seemed to favor the former category. For reasons stated previously, a granulomatous or gummatous pulmonary lesion caused by syphilis was entertained. The rarity and lack of characteristic diagnostic findings in gumma of the lung made this diagnosis seem unlikely when the incidence and varied clinical picture of pulmonary neoplasms was considered.

Operative Procedure and Findings. The left pleural cavity was entered posterolaterally through the bed of the 8th rib. A markedly thickened, adherent, and extremely vascular pleura with small yellow plaques was encountered posteriorly. There were less dense adhesions over the diaphragm. After the left lower lobe had been freed of all its pleural attachments, it was found to be reduced to half its normal volume. The lobe aerated normally except for the posterior basal division which was firm and rubbery to palpation. The mass felt more like an inflammatory than a neoplastic one. There were

numerous enlarged, anthracotic lymph nodes which bled more than usual on manipulation. These were located at the base of the fissure and in the region of the inferior pulmonary vein.

An adequate biopsy of the thickened pleura was taken for frozen section, and reported as nonspecific chronic inflammation by the surgical pathologist. A left lower lobe lobectomy was then performed. The appropriate vessels were ligated individually and silk technic was used throughout the operation. Two hundred thousand units of penicillin were instilled into the pleural cavity before closure of the chest wall. A fenestrated rubber tube was brought out through the ninth interspace in the mid axillary line and attached to a water-seal drainage apparatus. On return of the patient to the ward, a negative pressure of 6 centimeters of water was applied to the drainage tube.



FIG. 3.—Lower lobe of left lung showing the gray rubbery lobular mass occupying most of the lobe and reaching the pleura. Base of lung is to the left.

Postoperative Course. Four hundred thousand units of penicillin were given intramuscularly to the patient daily for 8 days following the operation. Forty-eight hours after surgery, the drainage tube was removed. The wound healed well and the patient made an uneventful recovery. He was discharged on the 10th postoperative and 44th hospital day to be followed in the chest surgery and dermatology out-patient departments. On his most recent visit to the clinic 8 months later, he was completely asymptomatic except for infrequent episodes of slight discomfort in the anterior portion of his scar. His physical and roentgenographic findings were not remarkable, and his daily activities were as before the onset of his illness.

Pathology. Gross. The lower lobe of the left lung measured 15 x 6 x 6.5 cm., and the visceral pleura was everywhere smooth and glistening, except for a 7 x 5 cm. area laterally which was thickened. In this region several small thin yellow plaques were found. The lobe was moderately heavier than usual. Palpation disclosed an irregularly nodular firm mass occupying most of the lobe and involving the pleura laterally. Only the apical region and basal area medially were unoccupied by the lesion.

GUMMA OF THE LUNG

On cut surfaces, (Fig. 3) a wedge-shaped nodular mass 7 x 7 x 4 cm. was seen in the dorso-lateral area near the base of the lobe. The apex of the mass directed toward the hilum and extended within 2 cm. of the main stem of the lower lobe bronchus. The lesion was rubbery, firm and yellow-grey in color. It consisted of well circumscribed though coalescent nodules which extended to the pleura laterally. The pleura in this vicinity was thickened, firm and light grey, while elsewhere it was thin and pliable. On manipulation of the lobe a unique finding was noted when the mass partially separated from the adjacent tissue. The parenchyma in the dependent areas of the lobe was normally crepitant and air-containing, but at the hilum it was beefy red, congested and soft.

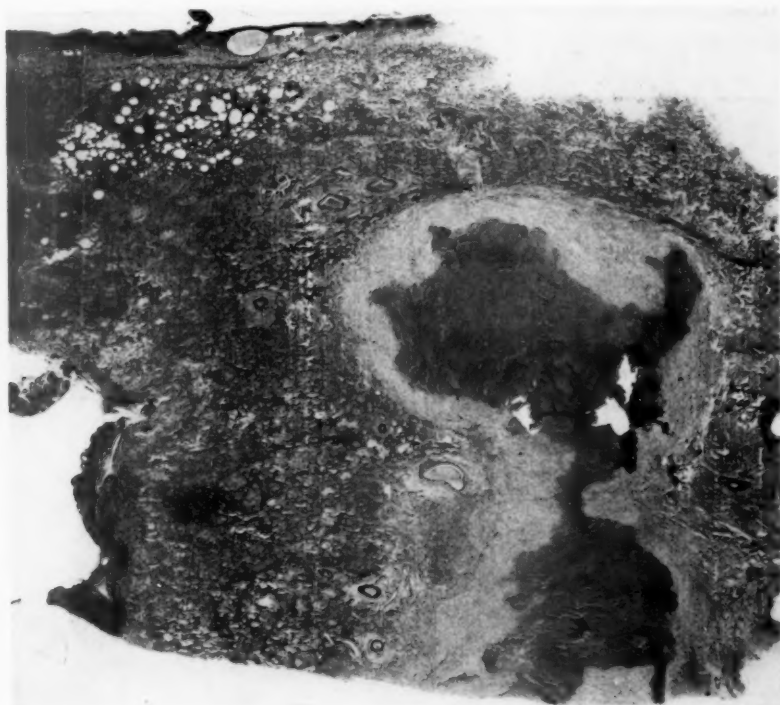


FIG. 4.—Low power photomicrograph of a small area of necrosis surrounded by a zone of fibrosis. Note exudative process in adjacent parenchyma.

Microscopic. The grey elastic material was composed of coalescent nodules of necrotic material in which the ghosts of former cell structure could be identified frequently (Figs. 4 and 5). The necrotic material was nowhere caseous in nature. It was a coagulative type of degeneration around which a dense wall of mature fibrous tissue had developed.

These connective tissue fibers were separated from one another by empty angular spaces, particularly in areas adjoining the necrotic tissue. There was considerable infiltration by chronic inflammatory cells of which large mononuclear phagocytes and plasma cells predominated. Many of the phagocytes had ingested a brown granular refractile pigment, while others were filled with a finely granular lipoid substance. Occasional multinucleated giant cells were found. Perivascular cuffing of the small blood vessels was not a prominent feature and sclerosis of arteries and veins was not particularly remarkable. No organisms were seen in the Levaditi stained sections.

DISCUSSION

Only a few of the reported cases of pulmonary gummata have been verified by pathologic study. This is probably due to the rarity of the disease and also because it is difficult to demonstrate the specific spirochete on microscopic sections. Recently, the source material for reports has changed. Whereas the material for discussion in early periodicals was derived from autopsy findings, the papers on this subject during the past few years have concerned patients living with the disease. These recent articles, therefore, have discussed the clinical recognition of late acquired pulmonary syphilis without post mortem confirmation.

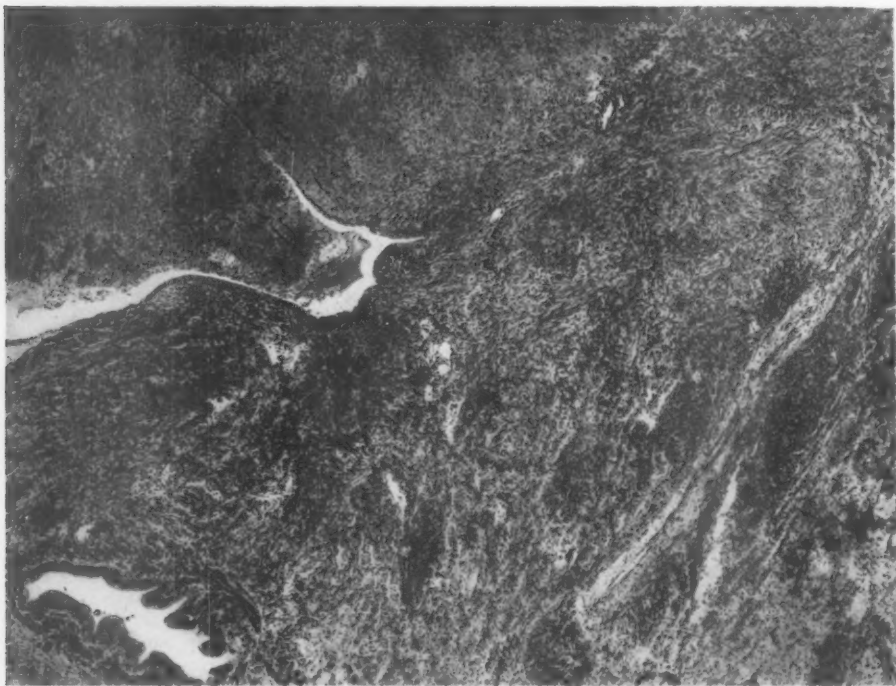


FIG. 5.—Medium power photomicrograph showing coagulative necrotic process eroding a small bronchus with an adjacent zone of fibrosis. No functional parenchyma is evident.

Gumma of the lung is twice as common in males as females, but the course of the disease in the latter is more fulminating.⁸ Karshner⁷ found that its peak of incidence is in the fourth decade of life, while Wohlhill¹⁵ noted that it is more common in the warmer climates. Excellent reviews of this subject have been written by Karshner,⁷ Carrera,¹ Howard⁶ and more recently by Lieu.⁹

The symptomatology of pulmonary gumma is like that of any chronic, low-grade infection of the lung. The onset is usually insidious and occurs late in the tertiary phase of lues. The lesion may be present without disturbing the host. Wilson¹⁴ has listed the symptoms in order of their frequency. Cough is

GUMMA OF THE LUNG

most often present and it is apparently persistent and extremely bothersome. Occasionally it is productive of small amounts of mucopurulent sputum. The patient may complain of dyspnea out of all proportion to the size of the lesion. Hemoptysis is relatively uncommon, but there may be either streaking of the sputum or copious bleeding. Fever and chills are usually absent. Chest pain may occur with extension of the disease process to the pleura. Some patients have complained of tightness in the chest.

The malady often simulates tuberculosis and both diseases may occur simultaneously. The gummas, however, usually cause a milder clinical course. Although gummas have been found in all lobes of the lungs, most authors agree that the right middle and both lower lobes are affected most commonly.

The physical findings are those of pulmonary consolidation. Dullness and rales may be noted depending on the location of the lesion. The presence of diminished breath sounds or bronchial breathing will depend on the patency of the bronchus or bronchi leading to the gumma. Pleural thickening will dampen the auscultatory findings, and contraction of the involved lung will distort the normal relationships of the adjacent intrathoracic structures.

Certain laboratory procedures may render corroborative evidence to the diagnosis of the disease in question. A positive blood Wassermann test will be of assistance, but if antiluetic therapy has been instituted, the serology may be negative. Pulmonary tuberculosis should be ruled out by repeated examinations of sputum concentrates or gastric washings for acid fast bacilli by competent technicians. The sputum should also be investigated for mycotic and non-specific spirochetal organisms. The intradermal reaction to old tuberculin is usually of little aid in the age group of these patients.

Very few cases of proven gumma of the lung have been studied roentgenographically.⁸ The criteria for diagnosis by this method are therefore not well established. On reviewing the reported cases it is evident that there are no characteristic roentgenographic features of the disease. It usually produces much the same picture as tuberculosis or other types of chronic pneumonitis with secondary fibrosis. Like tuberculosis, it crosses anatomic boundaries and may involve two or more pulmonary segments. If the lesion responds to medical therapy, there may be fibrosis and contraction of the affected parenchyma.

The more common diseases such as tuberculosis, neoplasm, and chronic pneumonitis should be excluded before the diagnosis of pulmonary gumma is considered. A bronchoscopy should be performed to rule out a bronchogenic growth that might be seen. A luetic pulmonary lesion may cause a stricture of an involved bronchus,³ and there may be moderate endobronchial inflammation in the region of the gumma.¹¹ Hartung and Freedman⁵ emphasize that a positive, well documented history of syphilis should be obtained.

The therapeutic test has been used as an aid in diagnosis. Reduction in the size of a pulmonary lesion roentgenographically following the administration of antiluetic drugs has been considered to be supportive evidence that a gumma was being treated.^{5, 8} It is recognized, however, that this procedure

may not help in determining the presence of such a lesion.¹⁴ If there is a reasonable suspicion of carcinoma, the duration of therapy should not be so prolonged that prompt surgical intervention is prevented.

The pathology of pulmonary gumma has been discussed and reviewed by many authors.^{1, 6, 12, 13} Summation of their findings includes a central area of coagulation necrosis with caseation surrounded by a varying degree of peripheral fibrosis which is infiltrated with lymphocytes, large mononuclear and plasma cells. There is associated bronchial and vascular destruction. Throughout the lesion, there is relative preservation of the elastic tissue elements.



FIG. 6.—Low power photomicrograph of gummatous tissue stained with acid orcein. Note persistence of elastic fibers in an otherwise degenerate material.

Carrera¹ and others have emphasized that the demonstration of *spirocheta pallida* in the lesion by microscopy is the ultimate in diagnosis. Howard⁶ has pointed out, however, that this has been accomplished rarely due to the inherent technical difficulties of such an examination. Following the institution of antiluetic treatment, and with the present widespread use of penicillin for all types of pulmonary infection, it is evident that the search for spirochetes in pathologic sections will be even more fruitless.

In the recent literature there have been numerous articles prescribing different types of medical therapy for luetic lesions of the lung.^{8, 10, 14} The recommended regimes have met with varying success. Diseased areas consisting primarily of inflammatory tissue may decrease markedly in size, leaving a small residual scar. Unfortunately, many of the reported lesions which have shown dramatic roentgenographic response to medical treatment have never

GUMMA OF THE LUNG

been proven or examined pathologically. Mercurials, bismuth compounds and iodides have been prescribed for the initial treatment of pulmonary gumma either singly or together.¹⁴ After maximum response to one or all of these drugs has been obtained, an adequate course of an arsenical, usually mepharsen, is given. Favorable results with penicillin therapy of late gummatous syphilis elsewhere in the body have been reported. Dexter and Tucker² found this drug useful in a series of 21 cases. More recently, however, Hahn⁴ discussed a case of a penile gumma which did not respond to 4,800,000 units of penicillin, although it later cleared with the administration of bismuth and mepharsen.

It is difficult to determine the prognosis of patients with pulmonary gummas. Many of the case reports in the early literature were based on post mortem studies following death from pulmonary pyogenic infection. The more recently published cases have had more satisfactory clinical courses, but usually the lesions in question have not been studied histologically. If a suspected gumma of the lung shrinks roentgenographically to a small shadow following the medical treatment outlined above, the prognosis is probably good. Warthin¹³ has emphasized, however, that if a considerable amount of pulmonary fibrosis remains, the affected portion of lung yields readily to pyogenic infection. Suppurative bronchiectasis may result with the destruction of bronchial walls. Carrera¹ noted that terminal bronchopneumonia occurred in a high percentage of his cases. He thought that this was aggravated undoubtedly by the effect of syphilis on the myocardium. Repeated hemoptyses may be a serious hazard to patients with pulmonary gummas.

Extirpative pulmonary surgery is being performed today with an increasing degree of safety. The exploratory thoracotomy has become an accepted and helpful diagnostic procedure in many clinics. A gumma of the lung is an uncommon disease, but it may simulate the more prevalent pulmonary neoplasm,¹⁰ which, if operable, requires immediate surgical attention. A clinician is indeed in a precarious position if he makes the diagnosis of gumma when the signs and symptoms of a patient can be interpreted as carcinoma. By the same token, if there is not an immediate and significant favorable response of the lesion to antiluetic drugs, an exploratory thoracotomy should be performed. An experienced thoracic surgeon usually can differentiate at operation between an inflammatory and a neoplastic pulmonary lesion.

If a clinician encounters a pulmonary lesion which has all the presumptive criteria of a gumma, and if this lesion does not respond to medical treatment, there is good reason to believe that permanent and serious parenchymal destruction has taken place. Unlike a gumma elsewhere in the body, such a disease in the lung will be exposed later to repeated secondary pyogenic infections, or it may be a potential source of hemorrhage. Since the disease usually occurs in the dependent portions of the lungs, subsequent bronchiectasis or suppurative disease may develop. It would seem logical, therefore, that such a permanently damaged area of lung should be removed either by lobectomy or segmental lobectomy.

SUMMARY

The clinical features and pathology of gumma of the lung have been discussed. The case presented was first treated with penicillin and then by resection of the diseased lobe. A rationale for surgical treatment of pulmonary gumma is presented.

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CONGENITAL MICROCOLON: A Case Report*

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CONGENITAL STENOSIS of the intestine is an uncommon condition, occurring about once in 20,000 births.¹ It is generally agreed that most of these obstructions are due to intraluminal causes. Davis and Poynter² noted that multiple sites of atresia are found in about 15 per cent of intestinal tracts so affected. A complete survey of the literature dealing with congenital microcolon up to the year 1925 was published by Grieg.³ He reported that even including atresia ani, congenital defects of the intestine are more frequently seen in the small bowel than in the colon. The duodenum is the most common site of the lesion; the ileum is the second most usual area of involvement.¹

Arnheim⁴ searched the literature to 1945 and learned of only 11 successful operations performed on jejunal and ileal atresia. His publication provided the twelfth reported cure of infra-duodenal atresia, and proved to be the second such cure effected in the presence of complicating perforation and peritonitis. In the past 35 years, more adequate roentgen-ray visualization⁵ and earlier surgical intervention⁶⁻⁸ have progressively and favorably influenced the prognosis for congenital anomalies of the gastro-intestinal tract.

The case to be presented in this communication is of interest because a remnant of what appeared to be the intestinal end of the vitello-intestinal duct was clearly defined. In addition, the characteristic clinical and surgical pictures of congenital stenosis of the ileum and colon were observed.

CASE REPORT

J. G., a white female of Jewish extraction, was delivered vaginally at term October 17, 1947, and appeared grossly normal at birth. The birth weight was 7 pounds, 6 ounces. The child was the second-born of healthy, young parents. Family history was negative.

Some 12 hours after birth the infant vomited several times, bringing up bile-tinged material, and her abdomen became progressively distended. Nothing had been passed by rectum since birth. A rectal catheter could be passed to a distance of only 5-7 cm. The clinical diagnosis was confirmed by barium enema roentgenograms. Blood examination and urinalysis provided normal findings.

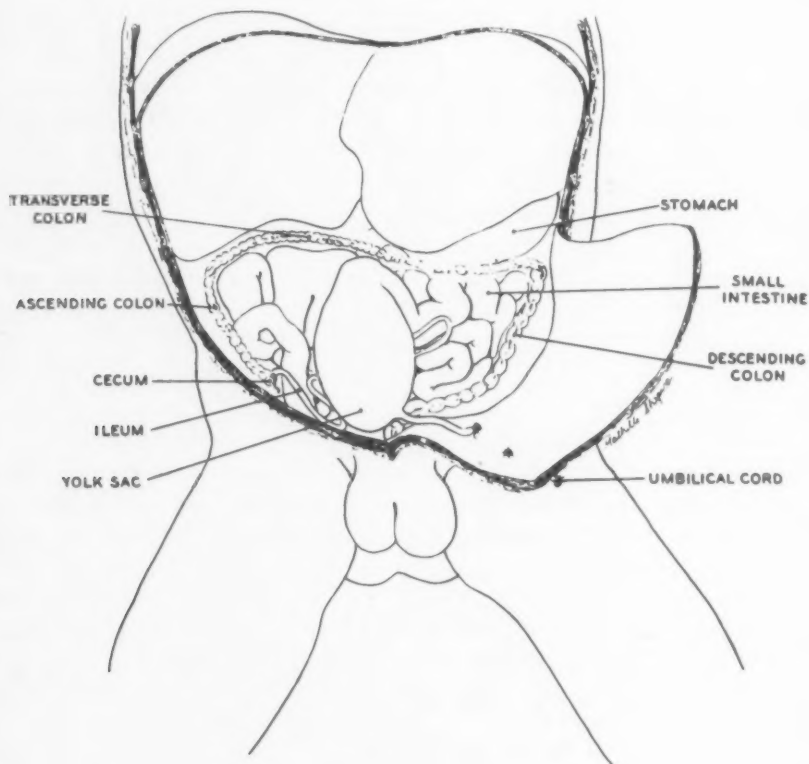
Under open drop ether anesthesia a laparotomy was done 24 hours after birth. The entire colon and terminal ileum were found to be narrowed to about the thickness of a pencil, *i.e.*, about 1 cm. in width, although a lumen was present throughout. The small intestine was markedly distended, immediately proximal to the stenosed ileum it was dilated, in egg-shaped form, to approximately 5 cm. in diameter. A small duct, measuring 2.5 cm. in length and 0.6 cm. in width was present between the dilated ileum and the umbilicus. This duct was ligated and severed (*cf.* Figure 1). A side-to-side anastomosis was made between the dilated ileum and descending colon, at the splenic flexure.

The infant was fed parenterally postoperatively and remained in good condition for 3 days. Oral feedings were attempted at this time, but food so administered was promptly

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regurgitated. A Miller-Abbott tube was passed into the duodenum on the 5th postoperative day, but could not be advanced beyond this point. Oral feedings were again not retained. Nothing was passed per rectum. The patient lost weight and her clinical course moved steadily downhill.

On the 10th day of life a second laparotomy was performed under open drop ether anesthesia. At this time a catheter was passed rectally and it extended through the anastomosis and into the ileum. The ileal dilatation was observed to have decreased in size at this time. In handling the bowel a rent was accidentally made in the colon, and fecal material escaped into the peritoneal cavity.



CONGENITAL MICROCOLON AND
PORTION OF ILEUM WITH YOLK SAC

FIG. 1

The postoperative course was stormy; there were frequent emeses; and repeated episodes of dyspnea and cyanosis supervened. The patient expired on her 18th day of life.

Autopsy Findings. The body is that of a poorly nourished and poorly developed white female infant. The skin and sclerae are moderately jaundiced. Right rectus incision 8-9 cm. in length near the midline and a second, smaller incision to the left of the umbilicus containing a "cigarette" drain, which exude a slight quantity of purulent material.

Heart weighs 30 Gm. (normal 19 Gm.) but valvular and myocardial measurements are normal. Lungs are grossly normal except for a few atelectatic patches. Brain shows engorgement of blood vessels, but otherwise normal.

CONGENITAL MICROCOLON

The small intestine is greatly distended with air and fecal material, and is covered with a patchy, yellowish exudate. The loops are tightly adherent, and multiple adhesions to the abdominal wall and abdominal organs are present. The wall of the third part of the duodenum appears gangrenous (probably caused by the mercury bulb of the Miller-Abbott tube), and its external surface is covered with thick, yellowish exudate. The ileocolostomy appears secure and functional. The underdeveloped terminal ileum measures 16 cm. to its cecal attachment, but is only 0.5 cm. in width. The lumen is patent. The ascending and transverse colon appear normal in length, but measure only 0.6 cm. in width. The descending and sigmoid colon measure 1.2 cm. in width. A normal appearing rectum admits a finger easily. The mucosa of the entire intestinal tract is dark red.

The liver is enlarged and weighs 222 Gm. (normal 123 Gm.). Surface and cut sections appear icteric. Histologically, hepatic lobules are compressed and individual cells show atrophic changes.

Left adrenal is twice the size of the right, and has convex and bulging surfaces. Cut sections reveal a pale, necrotic, cheesy material distending the medulla and compressing the cortex.

The right kidney weighs 18.3 Gm. (normal 15 Gm.), and the left 19.5 Gm. The cut surfaces show diffuse congestion, but cortical and medullary boundaries are readily distinguishable. Histologically, the tubular epithelium displays marked degenerative changes.

Cultures of brain and heart blood exhibit bacterial contamination. *E. coli* hemolytica grown from peritoneal fluid.

Pathologic Diagnosis: Peritonitis, ileocolostomy, hypoplasia and stenosis of terminal ileum, stenosis of entire colon, passive congestion of liver, cerebral congestion, jaundice.

COMMENTS

Not only the developmental mid-gut but also the caudal gut was involved in the congenital malformation observed in the above case. It appears highly improbable that faulty separation of the urogenital membrane in the process of definitive division of bladder and mesenteron occurred in this case, for such changes take place early in intrauterine life and anomalies of this origin involve lower segments of the colon. The duct observed here between ileum and umbilicus is more likely similar to a Meckel's diverticulum. Some error in reduction of the physiologic umbilical hernia may have participated in the production of this intestinal anomaly. Finally, the time-honored explanation of failure of re-establishment of the bowel lumen after epithelial hyperplasia had occurred may be prudently invoked⁹ despite Grieg's³ contention that congenital microcolon represents physiological rather than anatomical error.¹⁰

Although a gesture was made surgically to anastomose the ileum to the descending colon it was appreciated, during the operation, that the colon was too narrow to be of physiologic value. This conjecture was borne out by the infant's death eight days after the second operation.

SUMMARY

A case is presented of congenital stenosis of the terminal ileum and entire colon in a white female infant. There was a fatal outcome in 18 days despite two surgical efforts to correct the defects. A rather unusual finding was the presence of a duct which joined a portion of widely dilated ileum to the

umbilicus. Surgical cure was impossible by virtue of the extensive anatomical defects.

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